August 1966

MATERIALS DATA HANDBOOK

Aluminum Alloy 7075

Edited by

John Sessler
Volker Weiss

Sponsored by

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Huntsville, Alabama 35812

SYRACUSE UNIVERSITY RESEARCH INSTITUTE

DEPARTMENT OF CHEMICAL ENGINEERING AND METALLURGY

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Contract No. NAS8-11345

DEPARTMENT OF CHEMICAL ENGINEERING AND METALLURGY
SYRACUSE UNIVERSITY, SYRACUSE, NEW YORK

PREFACE

This Materials Data Handbook on the aluminum alloy 7075 was prepared by personnel and associates of the Department of Chemical Engineering and Metallurgy, Syracuse University, as part of a program sponsored by the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Huntsville, Alabama.

It is intended that this Handbook present, in the form of a single document, a comprehensive summary of the materials property information presently available on the 7075 alloy.

The scope of the information included herein includes physical and mechanical property data at cryogenic, ambient and elevated temperatures, supplemented with useful information in such areas as material procurement, metallurgy of the alloy, corrosion, environmental effects, fabrication and joining techniques. Design data are presented, where available, and these data are complemented with information on the typical behavior of the alloy. The major source for the design data used is the Department of Defense document, Military Handbook-5.

The Handbook is divided into twelve (12) chapters as outlined below:

Chapter	1	General Information
	2	Procurement Information
	3	Metallurgy
	4	Production Practices
	5	Manufacturing Practices
	6	Space Environment Effects
	7	Static Mechanical Properties
	8	Dynamic and Time Dependent Properties
	9	Physical Properties
	10	Corrosion Resistance and Protection
	11	Surface Treatments
	12	Joining Techniques

Information on the alloy is given in the form of Tables and Illustrations supplemented with descriptive text where deemed useful by the authors. Source references for the information presented are listed at the end of each chapter.

ACKNOWLEDGEMENTS

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Acknowledgement is made to the following Syracuse University personnel and associates for their contributions to the program.

Technical Editors	Reproduction
N. N. Breyer*	R. D. Ziemer
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John G. Sessler, Editor
Volker Weiss, Associate Editor

* Associate Professor, Dept. of Metallurgical Engineering, Illinois Institute of Technology.

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TABULAR ABSTRACT

Aluminum 7075

TYPE:

Wrought, heat treatable aluminum alloy

NOMINAL COMPOSITION:

Al-5.6Zn-2.5Mg-1.6Cu-0.3Cr

AVAILABILITY:

Bare and clad sheet and plate, rod, bar, wire, tube, extruded shapes, rolled rings, forgings and forging stock.

TYPICAL PHYSICAL PROPERTIES:

Density	2.80 gr/cm^3 at RT
Thermal Conductivity	0.313 cal/cm sec C at 20C (T6 temper) 0.372 cal/cm sec C at 25C (T73 temper)
Thermal Expansion	(20-100C), 23.2 x 10^{-6} in/in/C
Specific Heat	0.23 cal/gr cm at 100C
Electrical Resistivity	5.2 microhm-cm at RT (T6 temper)

TYPICAL MECHANICAL PROPERTIES

F_{tu}	33,000 psi (O temper) 83,000 psi (T6 temper
F_{ty}	15,000 psi (O temper) 73,000 psi (T6 temper)
e(2 inch)	17 percent (O temper) 11 percent (T6 temper)
E (tension)	10.4 x 10^6 psi

FABRICATION CHARACTERISTICS:

Weldability	Fusion methods not recommended. Resistance methods satisfactory in all heat treated tempers if proper procedures are employed.
Formability	Good in the annealed condition. Difficult to form in heat treated tempers.
Machinability	Good in the O, F or W tempers. More difficult in heat treated and hardened tempers.

COMMENTS:

A very high strength aluminum alloy with good forming and machining characteristics. Alloy is stress corrosion crack resistant in T73 temper.

SYMBOLS

a	One-half notch section dimension
A	Area of cross section; "A" basis for mechanical property values (Mil-Hdbk-5)
Å	Angstrom unit
AC	Air cool
AMS	Aerospace Material Specifications
Ann	Annealed
AUS	Austenitize
Av or Avg	Average
B	"B" basis for mechanical property values (Mil-Hdbk-5)
b	Subscript "bending"
bcc	Body centered cubic
BHN	Brinell hardness number
br	Subscript "bearing"
Btu	British thermal unit (s)
C	Degree (s) Centigrade
c	Subscript "compression"
CD	Cold drawn
CF	Cold finished
cm	Centimeter
c_p	Specific heat
CR	Cold rolled
CW	Cold worked
CVM	Consumable vacuum melted
D or Dia	Diameter
DPH	Diamond pyramid hardness
e	Elongation in percent
E	Modulus of elasticity, tension
E_c	Modulus of elasticity, compression
e/D	Ratio of edge distance to hole diameter
E_s	Secant modulus
E_t	Tangent modulus
ev	Electron volt (s)

F	Degree (s) Fahrenheit
f	Subscript "fatigue"
F_{bru}	Bearing ultimate strength
F_{bry}	Bearing yield strength
fcc	Face centered cubic
FC	Furnace cool
F_{cy}	Compressive yield stress
F_{su}	Shear stress; shear strength
F_{tu}	Tensile ultimate strength
F_{ty}	0.2% tensile yield strength (unless otherwise indicated)
G	Modulus of rigidity
HAZ	Heat affected zone in weldments
hcp	Hexagonal close pack
hr	hour (s)
HT	Heat treat
IACS	International annealed copper standards
in	inch
ipm	inches per minute
K	Stress intensity factor; thermal conductivity
K_c	Measure of fracture toughness (plane stress) at point of crack growth instability
K_{Ic}	Plane strain fracture toughness value
KSI or ksi	Thousand pounds per square inch
K_t	Theoretical elastic stress concentration factor
L	Longitudinal
lb	Pound
LT	Long transverse (same as transverse)
M	Bending moment
m	Subscript "mean"
Max	Maximum
MIL	Military
Min	Minimum
N	Cycles to failure
NSR	Notch strength ratio
NTS	Notch tensile strength

OQ	Oil quench
ppm	Parts per million
pt	Point
r	radius
RA	Reduction in area; Rockwell hardness A scale
RB	Rockwell hardness B scale
RC	Rockwell hardness C scale
ρ (rho)	Density
rpm	Revolutions per minute
RT	Room temperature
SA	Solution anneal
sec	second
S-N	S = stress; N = number of cycles
Spec	Specifications; specimen
ST	Solution treat; short transverse
T	Transverse
t	Thickness; Time, hour
Temp	Temperature
typ	Typical
Var	Variable
VHN	Vickers' hardness number
W	Width
WQ	Water quench

CHAPTER 1

GENERAL INFORMATION

1.1 Aluminum alloy 7075 is a high strength heat treatable wrought alloy developed by the Aluminum Company of America in 1943. The alloy contains zinc, magnesium, chromium and copper as hardeners plus small additions of other elements.

1.2 Aluminum 7075 responds to an age-hardening heat treatment to produce exceptionally high mechanical properties. This alloy, however, exhibits some degree of notch sensitivity. The alloy has good formability in the annealed and solution treated conditions at ambient temperatures, and in the T6 Condition at elevated temperatures. Alloy 7075 exhibits good machining qualities in the annealed state and little or no warpage occurs during the age hardening treatments. Its corrosion resistance is good and improves further with heat treatment and aging. The alloy is stress-corrosion cracking resistant in the T73 temper. 7075 can be resistance welded, but fusion welding is generally not recommended. The 7075 alloy is available in the full commercial range of sizes for sheet and plate, extrusions, forgings, bar, rod, wire and tube. Alclad sheet and plate are also available, (Refs. 1.1 thru 1.5).

1.3 Typical areas of application for the 7075 alloy are in aircraft structures, piping systems, mobile equipment and high pressure hydraulic units.

1.4 General Precautions

1.41 This alloy exhibits sensitivity to stress concentration (notch sensitivity), particularly at cryogenic temperatures, and this sensitivity should be recognized in the use of this material.

1.42 Overheated material exhibiting eutectic melting or high temperature oxidized material should not be used and cannot be salvaged by reheat treating.

1.43 Quench operations should be performed as rapidly as possible to develop full hardening potential.

1.44 Prolonged heating or repeated heat treatments of Clad material may cause diffusion of alloying elements into the coating and impair the resistance to corrosion.

CHAPTER 1 - REFERENCES

1.1 Alloy Digest, "Aluminum 7075", Filing Code Al-5, Engineering Alloys Digest, Inc., (February 1953)

1.2 "Aerospace Structural Metals Handbook", Vol. II Non-Ferrous Alloys, (V. Weiss and J. Sessler, Editors), ASD TDR 63-741, (1963) Revised 1964 and 1965

1.3 "Materials in Design Engineering", Materials Selector Issue, (Mid-October 1964)

1.4 "The Aluminum Data Book", Reynolds Metals Co., (1965)

1.5 "Alcoa Aluminum Handbook", Aluminum Co. of America, (1962)

CHAPTER 2

PROCUREMENT INFORMATION

2.1 General. Aluminum alloy 7075 is available in the full commercial range of sizes for sheet, strip, plate, bar, wire, seamless tube, forgings, shapes and extrusions. Detailed tables of standard sizes and tolerances for the various products available are given in Refs. 2.1 and 2.2.

2.2 Procurement Specifications. Specifications that apply to the 7075 alloy as of May 31, 1965, are listed in Table 2.2 for various products and tempers.

2.3 Comparison of Specifications. Federal procurement specifications are applicable to 7075 extruded bar, rod, shapes and tube; rolled or drawn bar, rod, wire and shapes; bare and Clad sheet and plate (also Clad one side only); forgings and rivet wire. Military specifications apply to sheet and plate (Clad one side only), forgings and impact extrusions. ASTM specifications apply to all wrought products except roll tapered Clad sheet and plate and Clad sheet and plate and Clad one side only, forging stock and impact extrusions. AMS specifications cover all wrought products except rivet wire.

2.4 Major Producers of the Alloy. (United States only)

Aluminum Company of America
1501 Alcoa Building
Pittsburgh, Pennsylvania

Harvey Aluminum
General Offices
Torrance, California

Kaiser Aluminum and Chemical Corp.
919 North Michigan Avenue
Chicago, Illinois

Reynolds Metals Company
6601 West Broad Street
Richmond, Virginia

Olin-Mathieson Chemical Corporation
460 Park Avenue
New York, New York

2.5 Available Forms, Sizes and Conditions

2.51 The available forms, sizes, conditions and tolerances for various 7075 alloy products are given in detail in Refs. 2.1 and 2.2.

PROCUREMENT SPECIFICATIONS (a)

TABLE 2.2

Source	(Refs. 2.3, 2.4, 2.6, 2.7, 2.8, 2.9, 2.10)					
Alloy	Al 7075					
Product	Temper	Military	Federal	ASTM	AMS	NASA-MSFC
Bar, rod, shapes, tubes (extruded or CF)	O	-	QQ-A-200/11B	B221-65	-	389
	F	-	-	B221-65	-	-
	T6	-	QQ-A-200/11B	B221-65	4154F	389
	T651	-	-	-	-	389
	T6510	-	QQ-A-200/11B	B221-65	4168A	-
	T6511	-	QQ-A-200/11B	B221-65	4169B	-
	T73	-	-	-	-	389
Bar, rod, wire, shapes (rolled or drawn)	O	-	QQ-A-225/9B	B211-65	-	389
	T6	-	QQ-A-225/9B	B211-65	4122C	389
	T651	-	QQ-A-225/9B	B211-65	4123B	389
	T73	-	QQ-A-225/9B	-	-	389

PROCUREMENT SPECIFICATIONS (a)

TABLE 2.2 (cont'd)

Source	(Refs. 2.3, 2.4, 2.6, 2.7, 2.8, 2.9, 2.10)					
Alloy	Al 7075					
Product	Temper	Military	Federal	ASTM	AMS	NASA MSFC
Sheet and plate	O	-	QQ-A-250/12C	B209-65	4044C	
	T6	-	QQ-A-250/12C	B209-65	4045C	
	T651	-	QQ-A-250/12C	B209-65	4038	
	F	-	QQ-A-250/12C	-	-	
Clad sheet and plate (both sides)	O	-	QQ-A-250/13C	B209-65	4048D	
	T6	-	QQ-A-250/13C	B209-65	4049D	
	T651	-	QQ-A-250/13C	B209-65	4038	
Clad sheet and plate (one side only)	O, T6, T651	MIL-A-8902	QQ-A-250/18C	B209-65	-	
	T6	-	QQ-A-250/18C	B209-65	4046	
	F	MIL-A-8902	QQ-A-250/18C	-	-	
Clad sheet and plate (roll taper)	T6	-	-	-	4047B	
Impact extrusions	O, F, T6	MIL-A-12545A	-	-	-	
	T6	MIL-A-12545A	-	-	4170	
Rivet wire	O, H13	-	QQ-A-430-1	B316-65	-	
Die forgings	T6	MIL-A-22771B	QQ-A-367F-1	B247-65	4139F	144B-1
	T652	-	QQ-A-367F-1	-	-	144B-1
	T73	MIL-A-22771B	-	-	-	144B-1
Hand forgings	T6	MIL-A-22771B	QQ-A-367F-1	-	4139F	144B-1
	T652	MIL-A-22771B	QQ-A-367F-1	-	-	144B-1
	T73	MIL-A-22771B	-	-	-	144B-1
Forging stock	T6	-	-	-	4139F	-

(a) Specified as of May 31, 1965

CHAPTER 2 - REFERENCES

2.1 "Standards for Aluminum Mill Products", 8th Edition, The Aluminum Association, (September 1965)

2.2 "Alcoa Aluminum Handbook", Aluminum Co. of America, (1962)

2.3 "Alcoa Product Data - Specifications", Section A12A, Aluminum Co. of America, (July 1963)

2.4 "1965 SAE Handbook", Society of Automotive Engineers, (1965)

2.5 "1963 Supplement to and Changes in Book of ASTM Standards, Part 2, Non-Ferrous Metals Specifications, Electron Tube Materials, Semiconductors", Am. Soc. Test. Mats., (1963)

2.6 "SAE Aerospace Materials Specifications", Soc. Automotive Eng., Inc., (Latest Index, Feb. 15, 1965)

2.7 "Index of Specifications and Standards", Department of Defense, Part I, Alphabetical Listing, and Part II, Numerical Listing, (September 1964), Supplemented (March 31, 1965)

2.8 "Light Metals and Alloys", ASTM Standards, Part 6, (October 1965)

2.9 MSFC-SPEC-144B, "Aluminum Alloy Forgings, Premium Quality, Heat Treated", (August 13, 1963), Amendment 1, (September 8, 1964), Custodian: NASA, Marshall Space Flight Center

2.10 MSFC-SPEC-389, "Aluminum Alloy, Bars, Rods, Wire and Special Shapes, Rolled, Drawn, Extruded or Cold Finished, 7075",(May 28, 1964) Custodian: NASA, Marshall Space Flight Center

CHAPTER 3

METALLURGY

3.1 Chemical Composition

3.11 Nominal chemical composition of 7075 alloy, in percent, (Ref. 3.1).

Zn	5.6
Mg	2.5
Cu	1.6
Cr	0.3
Al	Balance

3.111 Sheet and plate are available in the Alclad condition. Cladding material is 7072 alloy; nominal composition, in percent:

Zn	1.0
Al	Balance

Cladding may be applied to both sides or to one side only. The nominal cladding thickness per side is 4 percent of the toal composite thickness if the latter is 0.062 inch or below, 2.5 percent if the total thickness is between 0.062 and 0.187 inch and 1.5 percent if the total thickness is 0.188 inch or over. For thicknesses of 0.500 inch and over with 1.5 percent cladding, the average maximum thickness of cladding per side after rolling to specified plate thickness will be 3 percent of the plate thickness, as determined by averaging cladding thickness measurements taken at 100 diameter magnification on the cross section of transverse samples polished and etched for microscopic examination, (Ref. 3.1 and 3.2).

3.12 Chemical composition limits, in percent, (Ref. 3.1).

Zn	5.1 - 6.1
Mg	2.1 - 2.9
Cu	1.2-2.0
Cr	0.18-0.40
Fe	0.7 max
Si	0.5 max
Mn	0.3 max
Ti	0.2 max
Others	
Each	0.05 max
Total	0.15 max
Al	Balance

Conformity with these composition limits are normally checked by spectrochemical analysis or in accordance with the procedure outlined in ASTM E34, "Standard Methods for Chemical Analysis of Aluminum and Aluminum Base Alloys", (Ref. 3.1).

3.13 Alloying Elements. The principal alloying elements are zinc, magnesium, copper and chromium with lesser amounts of Fe, Si, Mn and Ti. The aluminum rich portions of the binary equilibrium diagrams for each of these principal elements are given in Figs. 3.1 and 3.2. The principal hardening constituent is a (Zn-Mg) phase. The particular combination of zinc, magnesium and copper, with the addition of 0.3 percent chromium, was selected for this alloy to give very high strength and good resistance to stress corrosion cracking, (Ref. 3.4). The amount of protection provided by cladding depends on the thickness and purity of the cladding material, and also on the heat treatments employed.

3.2 Strengthening Mechanism

3.21 General. The alloy is strengthened by precipitation hardening and cold work. Upon quenching from the solution temperature to room temperature, a (Zn-Mg) phase precipitation occurs in the form of submicroscopic particles which are obstacles to plastic flow and thus cause hardening. The major precipitating constituent has been identified as $MgZn_2$, (Ref. 3.5).

3.22 Heat Treatment, (Refs. 3.1, 3.2 and 3.6).

3.221 Anneal (O Condition): All products; heat to 413 to 454C, hold 2 to 3 hours, air cool, followed by heating to 232C for about 6 hours, (Ref. 3.6).

3.2211 Anneal to remove cold work. All products; heat to 349C. Time at temperature and cooling rate are not critical, (Ref. 3.2).

3.222 Solution Treatment (W Condition), (Ref. 3.6).

Rolled or drawn products: Heat to 460 to 499C, hold 10 minutes to 1 hour in salt bath or longer time in air and for heavy sections, quench in cold water. Sheet under 0.051 inch should be solution treated at 488 to 499C.

Extruded products: Heat to 460 to 471C, hold 10 minutes to 1 hour in salt bath or longer time in air and for heavy sections, quench in cold water.

Forged products: Heat to 460 to 477C, hold 10 minutes to 1 hour in salt bath or longer time in air and for heavy sections, quench in cold water.

Recommended soaking times for solution heat treatment of all wrought products are given in Table 3.1. Maximum allowable quench delay times are given in Table 3.2.

3.2221 Caution should be exercised in the control of the solution treating temperature. If the temperature is too high it may cause solid solution grain boundary melting which cannot be corrected by subsequent heat treatment operations. An example of grain boundary melting is shown in Fig. 3.3e. Low temperature may result in incomplete solution of the hardening constituents with a loss in hardening potential.

3.223 Precipitation Treatment (T6 Condition). Heat solution treated material to 110 to 127C, hold 22 hours minimum. Cooling rate is not critical, (Ref. 3.6).

3.224 Other Treatments: The alloy can also be hardened by cold work, but this procedure is not generally used to develop strength in commercial tempers except for rivet wire (H13 Condition). Cold work, however, is employed for stress relief and for straightening. The available tempers and treatments employed for various products are listed in Table 3.3.

3.3 Critical Temperatures. Melting range is approximately 477 to 638C.

3.4 Crystal structure. Face-centered-cubic matrix. The lattice parameter of aluminum decreases with the addition of zinc from $a_o = 4.0410$ Å at 0% zinc to 4.030 Å at 12.2 atomic percent zinc, (Ref. 3.4).

3.5 Microstructure. Fig. 3.3 illustrates typical microstructure of the 7075 alloy for (a) cold-rolled sheet, (b) annealed sheet, (c) solution treated sheet (W Condition) and (d) precipitation hardened sheet (T6 Condition). An example of grain boundary melting due to overheating is shown in Fig. 3.3e. Typical microstructures of "as-cast" material and preheated ingot are presented in Fig. 3.4.

Identificiation and distribution of the phases found in annealed and in solution heat treated material are given in Fig. 3.5. Hot working causes a breaking up and distribution of constituents as shown in Fig. 3.6. This figure also includes an example of $CrAl_7$ compound segregation which may occur if the Cr content is too high or the ingot casting temperature is too low. The segregation of this hard brittle compound can cause cracking, low strength and difficulty in machining, (Ref. 3.5).

References 3.5 and 3.7 are recommended as excellent sources of information on the identification of constituents and phases in aluminum alloys.

Metallographic Procedures: In general, mechanical polishing is preferred to electropolishing, especially where larger microconstituents are present and the material is relatively soft, as objectionable relief effects produced by the electrolytic polishing technique may cause a misinterpretation of the microstructure, (Ref. 3.5). For homogeneous alloys, and for those conditions containing only finely dispersed particles, the electrolytic method is excellent. Preparatory polishing on metallographic polishing papers 0 to 000 should be performed wet with a solution of 50g paraffin in 1 liter kerosene to keep the specimen bright and avoid imbedding of grinding compound particles into the soft specimen surface. Rough polishing on a "Kitten's Ear" broadcloth at 250 to 300 RPM with suspended 600 grade aluminum oxide and final polishing on a similar wheel at 150 to 200 RPM with heavy magnesium oxide powder is recommended, (Refs. 3.4 and 3.7).

An alternate and popular method consists of the following steps:

(a) Wet polishing (flowing water with 240 grit silicon carbide paper at approximately 250 RPM.

(b) Wet polishing with 600 grit silicon carbide paper at approximately 250 RPM.

(c) Polishing with 9 micron diamond paste on nylon cloth at 150 to 200 RPM using a mild soap solution for lubrication.

(d) Final polish on a vibratory polisher using a microcloth containing a slurry of methyl alcohol and 0.1 micron aluminum oxide powder. A slurry of 0.1 micron aluminum oxide powder in a 10% solution of glycerine in distilled water may also be used for this step.

Etching reagents should be suited to the objective of the study. Keller's etch reveals microstructural details and grain boundaries satisfactorily. A 10% solution of NaOH gives better details of the microstructural constituents but does not delineate the grain boundaries. Study of the "as polished" surface prior to etching may also give valuable information on the types of constituents present, especially when attention is paid to the colors of the various particles. Macroscopic studies of cracks, gross defects, forging lines and grain structure should be made with the etching solutions given in Table 3.4. Etching reagents for revealing microstructure are listed in Table 3.5.

SOAKING TIME FOR SOLUTION TREATMENT OF 7075 PRODUCTS

TABLE 3.1

Thickness (inches) [2]	Soaking time (minutes) [1]			
	Salt bath [3]		Air furnace [4]	
	(min)	(max) (alclad only) [5]	(min)	(max) (alclad only) [5]
0.016 and under	10	15	20	25
0.017 to 0.020 incl.	10	20	20	30
0.021 to 0.032 incl.	15	25	25	35
0.033 to 0.063 incl.	20	30	30	40
0.064 to 0.090 incl.	25	35	35	45
0.091 to 0.125	30	40	40	50
0.126 to 0.250 incl.	35	45	50	60
0.251 to 0.500 incl.	45	55	60	70
0.501 to 1.000 incl.	60	70	90	100
1.001 to 1.500 incl.	90	100	120	130
1.501 to 2.000 incl.	105	115	150	160
2.001 to 2.500 incl.	120	130	180	190
2.501 to 3.000 incl.	150	160	210	220
3.001 to 3.500 incl.	165	175	240	250
3.501 to 4.000 incl.	180	190	270	280

[1] Longer soaking times may be necessary for specific forgings. Shorter soaking times are satisfactory when the soak time is accurately determined by thermocouples attached to the load.

[2] The thickness is the minimum dimension of the heaviest section.

[3] Soaking time in salt-bath furnaces should be measured from the time of immersion, except when, owing to a heavy charge, the temperature of the bath drops below the specified minimum; in such cases, soaking time should be measured from the time the bath reaches the specified minimum.

[4] Soaking time in air furnaces should be measured from the time all furnace control instruments indicate recovery to the minimum 9th process range.

[5] For alclad materials, the maximum recovery time (time between charging furnace and recovery of furnace instruments) should not exceed 35 minutes for gages up to and including 0.102 inch, and 1 hour for gages heavier than 0.102 inch.

(Ref. 3.6)

MAXIMUM IMMERSION QUENCH DELAY

TABLE 3.2

Nominal thickness (inches)	Maximum time (seconds) [2]
Up to 0.016 incl.	5
0.017 to 0.031 incl.	7
0.032 to 0.090 incl.	10
0.091 and over	15

[1] Quench delay time should begin when the furnace door begins to open or when the first corner of a load emerges from a salt bath, and end when the last corner of the load is immersed in the water quench tank. The maximum quench delay times may be exceeded (for example, with extremely large loads or long lengths) if performance tests prove that all parts will be above 775° F when quenched.

[2] Shorter times than shown may be necessary to insure that the minimum temperature of 7178 alloy is above 775° F when quenched.

(Ref. 3.6)

TEMPERS AND TREATMENTS FOR BARE AND CLAD PRODUCTS

TABLE 3.3

Sheet	Plate	Rod and Bar (Rolled or CF)	Tube and Wire (Drawn)	Rivet Wire and Rod	Rolled Rings	Description of Treatment to Produce Indicated Temper
		F				As fabricated
O*	O*	O	O	O		See chapter 3, Section 3.221
T6*	T6*	T6	T6		T6	See chapter 3, Section 3.223
	T651*	T651				T6 + stress relief by stretching (a)
				H13		Cold worked to 3/8 hard condition
	T73	T73			T73	Proprietary thermal treatment

Rod and Bar (extruded)	Shapes (extruded)	Tube (extruded)	Die Forgings	Hand Forgings	Forging Stock	Description of Treatment to Produce Indicated Temper
F	F				F	As fabricated
O	O	O				See Chapter 3, Section 3.221
T6	T6	T6	T6	T6		See Chapter 3, Section 3.223
				T652		T6 + stress relief by compression
T6510	T6510	T6510				Stress relief by stretching (b)
T6511	T6511	T6511				Stress relief by stretching (c)
T73	T73	T73	T73	T73	T73	Proprietary thermal treatment

* Also available as Alclad on both sides or on one side only.

(a) 1.5 to 3 percent for sheet and plate
1 to 3 percent for rod, bar, shapes and tube
0.5 to 3 percent for drawn tube.

(b) No further straightening after stretching

(c) Minor straightening after stretching to comply with standard tolerances.

(Refs. 3.1 and 3.2)

ETCHING SOLUTIONS FOR REVEALING MACROSTRUCTURE

TABLE 3.4

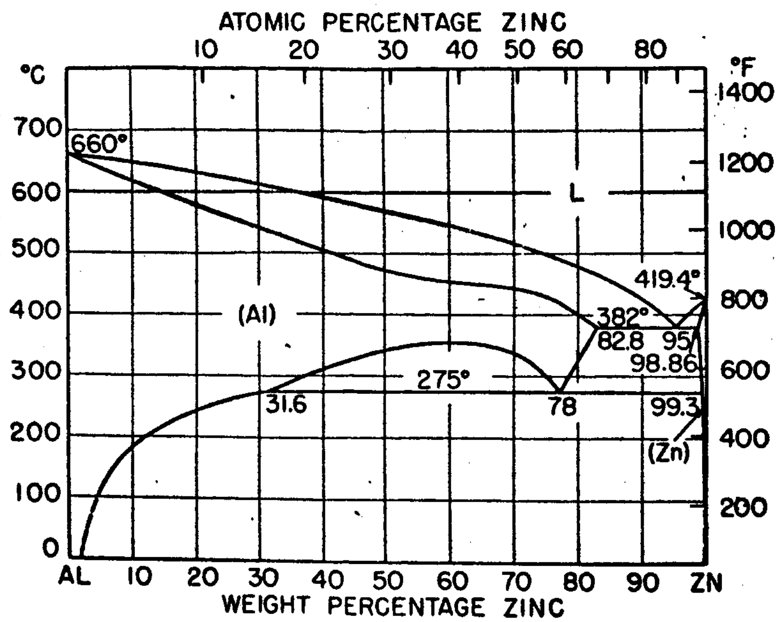
Source	(Ref. 3.4)		
Solution	Concentration (a)		Specific Use
Sodium Hydroxide	NaOH Water	10g 90ml	For cleaning surfaces, revealing unsoundness, cracks and gross defects
Tucker's	HCl (conc.) HNO_3 (conc.) HF (48%) Water	45ml 15ml	For revealing structure of castings, forgings, etc.
Modified Tucker's	HCl (conc.) HNO_3 (conc.) HF (48%) Water	10ml 10ml 5ml 75ml	For revealing structure of all castings and forgings except high silicon alloys.
Flick's	HCl (conc.) HF (48%) Water	15ml 10ml 90ml	For revealing grain structure of duralumin type alloys. Surface should be machined or rough polished.

(a) All of these solutions are used at room temperature.

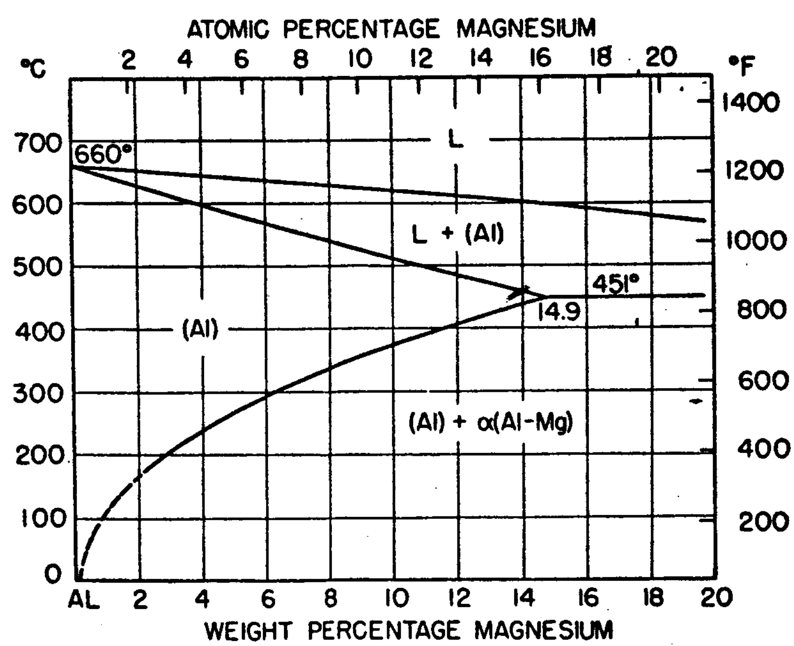
ETCHING REAGENTS FOR REVEALING MICROSTRUCTURE

TABLE 3.5

Source	(Ref. 3.5)			
No.	Composition		Uses	Remarks
1	NaOH H_2O	1g 99ml	General microstructure	Swab with soft cotton for 10 seconds
2	NaOH H_2O	10g 90ml	General microstructure (micro and macro)	Immerse 5 seconds at 160F, rinse in cold water
3	Keller's (conc.) HF (conc.) HCl (conc.) HNO_3 (conc.) H_2O	 10ml 15ml 25ml 50ml	General microstructure (micro and macro) for copper bearing alloys)	Use concentrated for macroetching; dilute 9 to 1 with water for microetching
4	Keller's (dilute) HF (conc.) HCl (conc.) HNO_3 (conc.) H_2O	 1ml 1.5ml 2.5ml 380ml	General microstructure of 7075 alloy	Etch for 5 seconds



ALUMINUM-ZINC

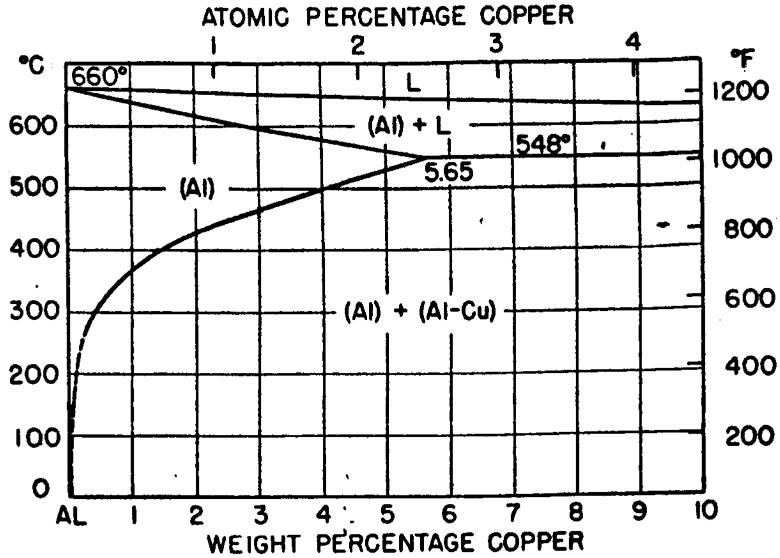


ALUMINUM-MAGNESIUM

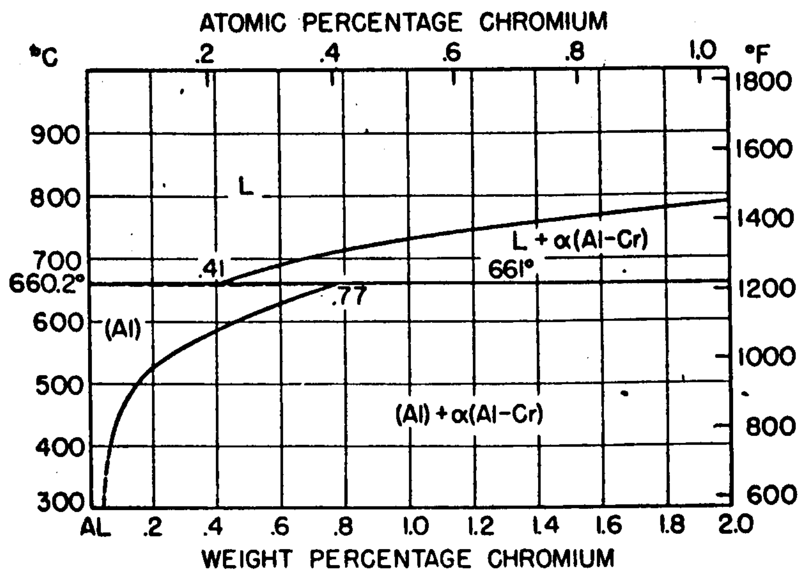
FIG. 3.1 ALUMINUM-RICH PORTION OF BINARY EQUILIBRIUM DIAGRAMS

(Ref. 3.3)

(Courtesy Aluminum Co. of America)



ALUMINUM-COPPER

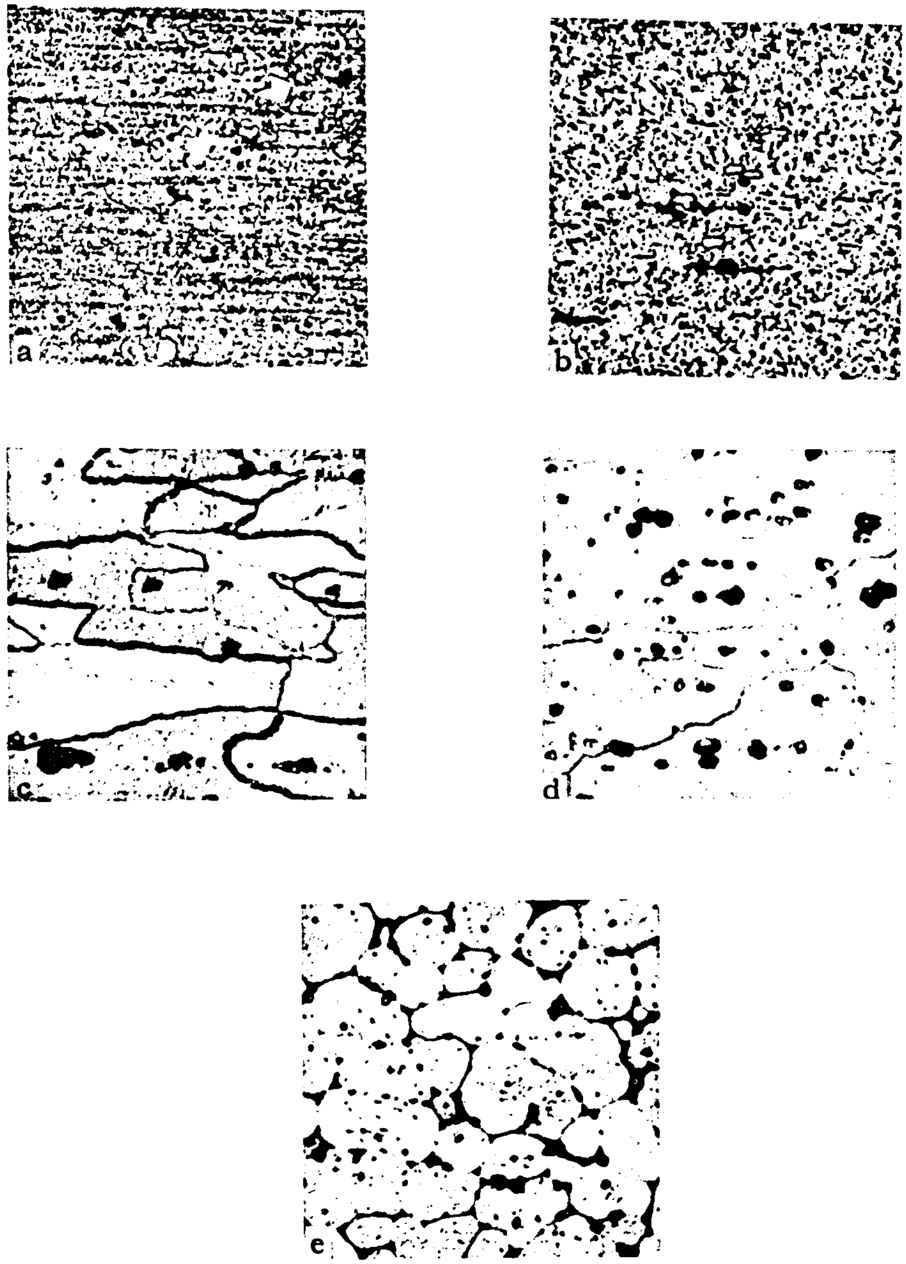


ALUMINUM-CHROMIUM

FIG. 3.2 ALUMINUM-RICH PORTION OF BINARY EQUILIBRIUM DIAGRAMS

(Ref. 3.3)

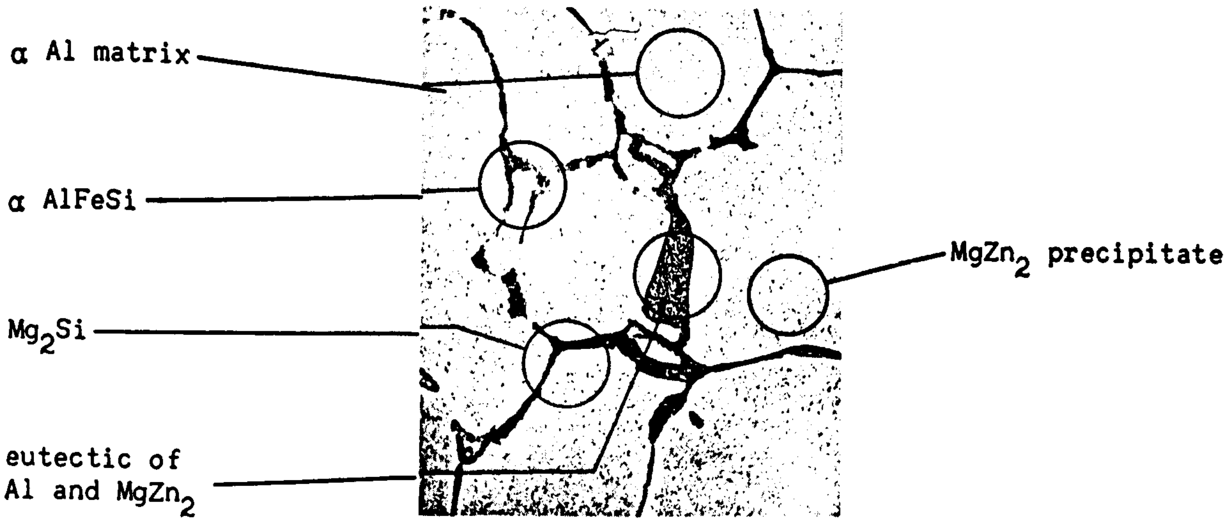
(Courtesy Aluminum Co. of America)



Keller's Etch 500X

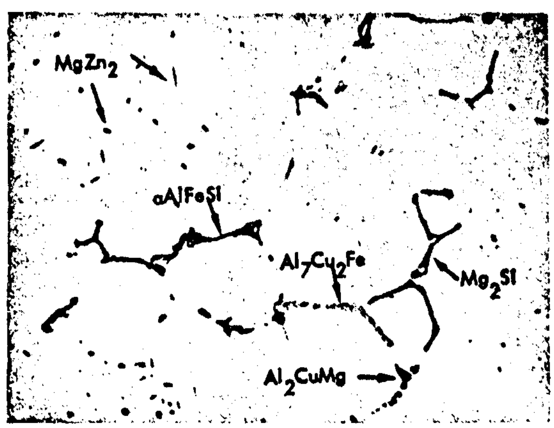
(a) Cold rolled sheet
(b) Annealed sheet (O temper)
(c) Solution treated sheet (W temper)
(d) Aged sheet (T6 temper)
(e) Grain boundary melting in overheated sheet

FIG. 3.3 TYPICAL MICROSTRUCTURES OF 7075 ALUMINUM ALLOY (Ref. 3.4)



AS CAST STRUCTURE

Keller's (dilute) 500X

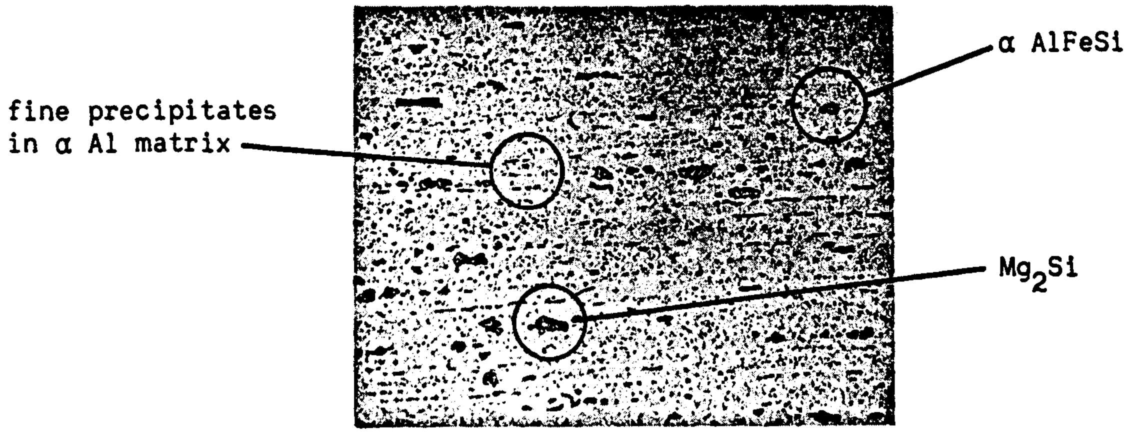


STRUCTURE OF PREHEATED INGOT

Keller's (dilute) 500X

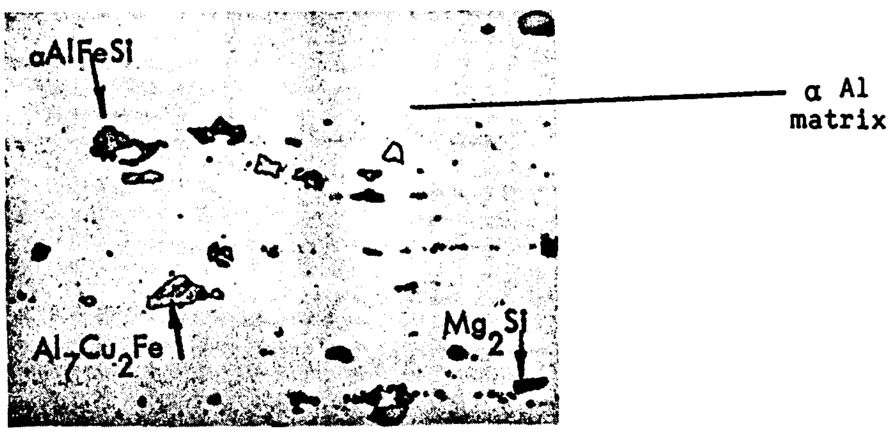
FIG. 3.4 TYPICAL MICROSTRUCTURES OF 7075 ALUMINUM ALLOY (Ref. 3.5)

(Courtesy Kaiser Aluminum & Chemical Corp.)



ANNEALED STRUCTURE (O temper)

Keller's (dilute) 500X



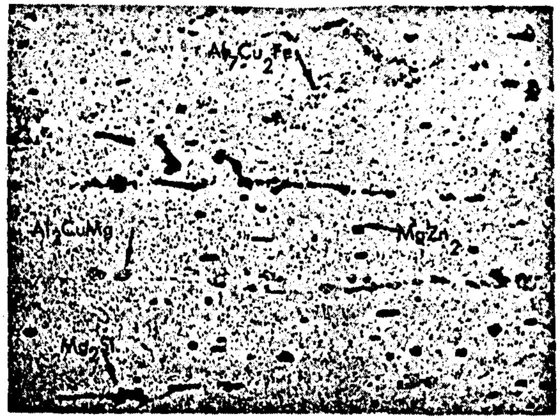
SOLUTION TREATED STRUCTURE (W temper)

Keller's (dilute) 500X

FIG. 3.5 TYPICAL MICROSTRUCTURE OF ANNEALED AND SOLUTION HEAT TREATED CONDITIONS

(Ref. 3.5)

(Courtesy Kaiser Aluminum & Chemical Corp.)



HOT WORKED STRUCTURE

Keller's (dilute) 500X

EXAMPLE OF Cr Al_7 SEGREGATION

Keller's (dilute) 250X

FIG. 3.6 EXAMPLES OF HOT WORKED AND SEGREGATED STRUCTURES

(Ref. 3.5)

(Courtesy Kaiser Aluminum & Chemical Corp.)

CHAPTER 3 - REFERENCES

3.1 "Standards for Aluminum Mill Products", Eighth Edition, The Aluminum Association, (September 1965)

3.2 "The Aluminum Data Book", Reynolds Metals Co., (1965)

3.3 E. H. Wright and L. A. Willey, "Aluminum Binary Equilibrium Diagrams", Technical Paper No. 15, Aluminum Co. of America, (1960)

3.4 W. L. Fink et al., "Physical Metallurgy of Aluminum Alloys", American Society for Metals, Cleveland, Ohio (1958)

3.5 J. P. Vidosic, "Study of Phase Identification in Steel and Aluminum Alloys", Georgia Institute of Technology, Final Report, Project A-641, NASA Contract NAS8-5117, (September 1963)

3.6 Military Specification, "Heat Treatment of Aluminum Alloys", MIL-H-6088C (October 15, 1962)

3.7 F. Keller and G. W. Wilcox, "Identification of Constituents of Aluminum Alloys", Technical Paper No. 7, Aluminum Co. of America, (1942), Revised 1958

CHAPTER 4

PRODUCTION PRACTICES

4.1 General. In the United States, aluminum and its alloys are produced from an ore of impure hydrated aluminum oxide known as "bauxite". Important sources of bauxite are located in Arkansas, Dutch Guiana and Jamaica. The impure ore is converted into pure aluminum oxide (alumina) through a series of chemical processes. Oxygen is removed from the alumina by smelting in carbon-lined electric furnaces known as reduction pots. Pure molten aluminum is deposited at the bottom of the pot, and is periodically siphoned off and poured into molds to form "pigs" and "sows". A separate furnace operation is used to form "alloy pig" from the pure aluminum by the addition of alloying elements, and this metal is cast into ingots for further processing, (Ref. 4.1).

For the 7075 alloy, the major alloying elements added are zinc, magnesium and copper plus a small addition of chromium. Generally, this phase of production practice involves the melting, alloying and casting of large 20,000 to 50,000 pound ingots, carefully controlled. After the ingots are scalped and preheated in vertical electric soaking pits, they are ready for further processing to a particular form of product.

4.2 Manufacture of Wrought Products

4.21 Bar and rod are normally produced by hot rolling or extruding. Cold finished bar and rod are produced by hot working to a size slightly larger than specified and reducing to final dimensions by cold working. A better surface finish and closer dimensional tolerances are obtained in this manner, (Ref. 4.2).

4.22 A similar process is used to produce rolled structural shapes; special rolls being required. Finishing operations include roller or stretch straightening, and heat treatment.

4.23 Roll form-shapes are produced by passing strip through a series of roller dies. Each successive pair of rolls cause the work to assume a cross-section shape more nearly approaching that desired. The final desired shape is produced at the last pair of rolls.

4.24 Plate is produced by hot rolling of ingots to slabs (approximately 60 percent reduction), usually in a 4 high reversible mill. The slabs are then further reduced 50 percent in a reversible 2 high mill. The last stage of hot rolling is done in a hot reversing mill, where the plate is progressively rolled to the final hot mill dimensions. Alloy plate may be subjected to "stress relief" stretching (about 2 percent permanent set) after solution treatment to improve flatness and reduce warpage upon machining. Plate is then sheared or sawed to the required dimensions, (Ref. 4.2).

4.25 Sheet is usually produced from plate by cold rolling to final sheet thickness, followed by trimming, tempering, heat treating, stretching and other finishing operations.

4.26 Wire is produced by drawing rod through a series of progressively smaller dies to obtain the desired dimensions.

4.27 Extrusions are produced by subjecting re-heated cast billets to enough pressure to force the metal to flow through a die orifice, forming a product whose cross-section shape and size conforms to that of the orifice. Speeds, pressures and temperatures must be closely controlled to insure uniform quality of extruded products.

4.28 Tube is produced by extruding, by drawing or by welding. Extruded tube is forced thru an orifice as described in 4.27. A die and mandrel are used. Drawn tube is manufactured by a cold process which is similar to drawing bar and rod. A mandrel is used with one end fixed and a bulb attached to the other end. The tube is drawn over the mandrel bulb and through a die at the same time. Welded tube is produced by slitting coil stock into strips and passing the strips through a series of rolls to form tube. The longitudinal seam is welded as the tube leaves the last roll forming station.

4.29 Forgings are made by pressing (press forging) or hammering (drop forging). Relatively heavy equipment is required since aluminum is not as plastic at its forging temperature as steel. Aluminum forgings compare favorably with structural steel in unit strength at about one-third the weight. With comparable strength and with a lower elastic modulus, aluminum alloys have a much higher impact-energy-absorbing capacity than a mild steel.

4.3 Casting of Alloy Ingots

4.31 Metal for wrought products is alloyed in large 10 to 25 ton double hearth furnaces, carefully controlled and instrumented. The direct chill (DC) method is generally used for casting these ingots. Molten metal is poured into a mold and a hydraulic piston descends slowly as the metal solidifies. Water is sprayed on the outside of the mold to promote rapid solidification. Additional processing may include scalping (machining of outside surfaces) or homogenizing, (Refs. 4.2 and 4.3).

CHAPTER 4 - REFERENCES

4.1 "Kaiser Aluminum Sheet and Plate Product Information", Second Edition, Kaiser Aluminum and Chemical Sales, Inc., (January 1958)

4.2 "The Aluminum Data Book, Aluminum Alloys and Mill Products", Reynolds Metals Co., (1958)

4.3 "Alcoa Aluminum Handbook", Aluminum Co. of America, (1962)

CHAPTER 5

MANUFACTURING PRACTICES

5.1 General. This heat-treatable alloy is one utilizing zinc, magnesium, copper and chromium which finds application for highly stress airframe construction. In general 7075 is used where very high strength and good resistance to corrosion are required, (Ref. 5.6) and is available as the base alloy and in the Alclad condition. It is produced in most of the wrought forms with the exception of pipe, structural shapes and foil (in the Alclad form it is available as sheet and plate, (Ref. 5.1).

5.2 Forming

5.21 Sheet and plate. The relative formability of 7075 is not as good as many of the other heat-treatable alloys. Regular methods can be used; however, more care and precision fabricating techniques are required, (Ref. 5.4). The relative formability compared with other heat-treatable alloys can be noted in Table 5.1.

5.211 Cold forming. The formability of alloy 7075 sheet and plate is directly related to the temper strength and ductility. In producing complex parts, the procedure is to use annealed sheet and to heat treat after forming. Because of its extra strength and hardness, 7075-T6 is relatively difficult to form. The simplest and most widely used forming method is probably that of bending. The ease of bending is indicative of most other forming operations. Table 5.2 indicates the ease of forming in terms of recommended minimum bend radii as a function of temper and sheet and plate thickness using typical mechanical properties for 0.100 inch sheet. Aluminum sheets are normally formed using operations such as:

1. Bending
2. Flanging
3. Rolling
4. Drawing
5. Pressing
6. Stretching
7. Embossing
8. Coining
9. Stamping
10. Spinning
11. Contour Forming

12. Bulging
13. Beading and Roll Flanging
14. Necking
15. Curling

The factors influencing bending of 7075 sheet, as spelled out previously, also influence the fourteen other forming operations in the same general manner. Because of the lower modulus of elasticity of aluminum compared with steel a much greater "springback" is encountered. Overforming is the common way of correcting the tendency. In addition reducing the bend radius, increasing sheet thickness and increasing the total amount of plastic deformation also decrease the extent of springback. Alloy 7075 sheet can be formed to many shapes by drawing if care is used. This extensively employed mass production method can be employed to produce simpler parts in a single draw. In the case of more complex parts the reduction and forming is accomplished using successive draws with frequent intermediate anneals. This practice avoids exhausting the ductility and introducing cracks. Deep draws normally employ male and female metal dies. Forming in rubber (Guerin Process) for relatively shallow parts is a method where several thin layers of rubber are confined in a pod holder or retainer made of steel or cast iron. A descending ram on which this holder is mounted causes the aluminum sheet to be compressed against a form block to make the required part. If the aluminum is made to flow against a female die using fluid pressures behind a rubber diaphragm the method is known as "hydroforming". Spinning and high energy rate methods have also been successful.

Alloy 7075 has been used for some recent applications such as engine nacelle covers and contoured wing skin panels.

5.212 Hot forming. Although hot forming (from 300 to 400F) is used to ease forming for many aluminum alloys, 7075 which responds to artificial aging may actually require more power for forming because of the strengthening which takes place at the elevated temperature, (Ref. 5.4). Many successful forming methods have been developed where the metal is heated in the area to be formed. However, this practice can lead to undue softening of the material unless certain precautions are exercised. The maximum reheating periods which are recommended are as shown in Table 5.3. The effect of forming temperature on springback of sheet in T6 Condition is shown in Fig. 5.1. The effect of forming at elevated temperatures on room temperature tensile properties of plate in O Condition prior to forming, and T6 Condition after forming, is shown in Fig. 5.2. Fig. 5.3 indicates the effect of forming temperature on bend factor in rubber forming of sheet.

5.22 Shapes and tubes. Either extrusion or rolling can be used to produce aluminum shapes. The relative formability of alloy 7075 as tubes or extrusions can be noted in Table 5.4. The alloy, as has been pointed out, is one of the more difficult to form of the aluminum alloys. Sections in the O temper or W temper are bent and formed more easily than those in the T6 or T73 heat treated tempers.

Stretching, wiping or rolling are general methods used to form shapes and tubes. Sheets, shapes and tubes are stretch formed by clamping at one end and pulling or stretching over a single male die so as to exceed the elastic limit. The metal section takes the shape of the die by stretching or elongating more in the heavier curvature areas than in the shallower ones. When working exceptionally thin-wall round, square or rectangular tube on small radii, it is necessary to add a wiper and a flexible mandrel to provide extra support for the tube at the point of bending. Rolls can also be used for the forming, using dies to form the contour.

5.23 Forging. The very high strength 7075 is more difficult to forge than most other aluminum alloys. The high strength-to-weight ratio makes this alloy desirable for jet landing gear and other similar applications.

Forgings are made using either the open die or closed die methods and by impact or pressure. Prototype or other few-of-a kind needs for aluminum parts usually do not warrant the cost of forging dies. Small runs are made using the hand forging open die techniques where the heated stock is worked between flat or simple dies that impose little or no lateral confinement on the material. Hand forgings over a ton in weight can be made. Hand forgings are provided in various tempers which are defined in Table 5.5.

As in all forgings there is grain flow in 7075 which is characteristic of the forging process. The resultant grain pattern results in anisotropy of properties and this must be considered for property evaluations. The process for most production forgings starts with the stock which can vary from 3/8 inch to 4 inches square stock, and rectangles from 3/8 inch for the minimum dimension to as much as 10 inches on the maximum dimension. Conditioning to remove localized surface defects is permitted at this point.

The stock is carefully heated in the range of 600 to 900F. The relative forgeability of 7075 as a function of the forging temperature can be compared to other aluminum alloys in Fig. 5.4. It can be seen that this alloy is the most difficult to forge. The mechanical properties are a function of the forging direction as well as the size of the hand forging. Fig. 5.5 shows the test bar orientation as a function of the principal directions.

Large production runs are made using closed dies. The cost of the die is pro-rated against the number of pieces contemplated. Either drop forging or press forging machinery is used. After preheating, the stock is formed in one step or in the case of complicated parts in several operations which may involve reheatings. Dies in the forging operation are heated with auxilliary gas or electric heaters. The flash resulting from excess metal overfilling the mold is removed by hot or cold trimming, sawing or grinding.

Holes in the forging are pressed to produce "punchouts". Sometimes the punchout is combined with the trim operation. Very close tolerances can be met in a standard forging by die coining (cold) to precise dimensions, usually within a few thousands of an inch.

Straightening after heat treatment is often a required operation. Templates combined with indicators and other gages are used to determine the out-of-tolerances. Straightening ranges from hand straightening to "cold restrike" operations. The forgings are inspected for grain flow, mechanical properties,dimensions and ultrasonic soundness.

5.3 Machining

5.31 Conventional machining. The aluminum alloy 7075 has good machinability in all conventional machining operations. Hand forgings of 7075 which require a large amount of metal removal by roughing out before heat treatment should be machined in the F-temper. In those cases where hand forgings are to be machined to very close dimensions, with the additional requirement for a good surface condition, the W temper yields optimum results. Small hand forgings can be machined successfully in the T6 temper.

It is difficult to produce a precise tabulation of machining parameters for each of the different types of operations. However, Table 5.6 is a compilation of typical factors for many common machining operations, (Ref. 5.9). Grinding typically uses a wheel of 6000 ft/min and a table speed of 60 ft/min. The down feed will produce a rough finish if it is kept about 0.001 inch per pass. A fine finish will be produced if the down feed is kept to a maximum of 0.0005 inch per pass. The cross-feed is approximately one-third of the wheel width. The wheel type is A46KV with a water-base emulsion or chemical solution for the grinding wheel.

The 7075 alloy has been machined to produce contoured wing skin panels by a huge three-gantry machine, (Ref. 5.13). Three inch slabs, 4 to 5 feet wide by 6 to 12 feet in length, were first straightened by "stretcher-leveling" to the 7075-T651 Condition. This treatment minimized distortion from the skin-milling. The entire operation of producing 2 1/2 inch deep cavities was numerically controlled. The vacuum held slabs produced the required section with excellent tolerances.

5.32 Electro-chemical and chemical machining. Weight reductions such as the cavity machining by slab milling require large rigid machines. These weight reductions are important for space vehicle components particularly large boosters, where the fuel and oxygen tanks are fabricated from precurved cylindrical and spherical sections of high-strength aluminum alloys. The use of sections which are "integrally stiffened" by ribs which are left intact while the bulk of the metal stock is removed has been examined for both electrochemical and chemical methods. In some cases chemical milling will allow early production of initial units without requiring the delay times inherent in the fixturing for production, (Ref. 5.14).

5.322 Electro-chemical milling. Electrochemical machining for metal shaping subjects the chemically erodible workpiece to the action of anodic current flow in a suitable electrolyte. A second electrode which is the tool is provided for the cathodic action. The basic principles are the same as those generalized in Faraday's Law of Electrolysis. However, the electro-chemical machining, or ECM, process is the reverse of electro-deposition or electroplating. An exception is that the cathodic process involves the evolution of hydrogen, in most cases, rather than the electrodeposition of a metal. There are a number of tool workpiece configurations that may be employed in the ECM process depending upon the particular type of metal removal geometry desired. It is normally required that fresh electrolyte is supplied to the workpiece. Alloy 7075 is essentially pure aluminum as far as the rate of the electrochemical process is concerned. Hence, from the Faraday Laws it is rather easily shown that 1.26 cubic inches of the metal can be removed per minute at 100,000 amperes (assuming 100% efficiency). In practice efficiencies of 80 to 90% are encountered. An electrolyte of 5 to 10% NaCl solution has been found to yield excellent results and the process can be carried out using voltages of 10 to 15 volts. The milling rate of the ECM process depends upon the current capacity of the power supply and the ability of the electrolyte system to provide fresh electrolyte. High electrolyte pressure requirements of 100 to 250 psi provide even electrolyte flow and satisfactory cutting conditions. Temperatures of about 120F produce good quality finishes.

5.323 Chemical milling. The removal of metal stock by chemical dissolution or "chem-milling" has many potential advantages over conventional milling methods. The removal of metal by dissolving in an alkaline or acid solution is now routine for specialized operations on aluminum, (Ref. 5.6). For flat parts, on which large areas having complex or wavy peripheral outlines are to be reduced only slightly in thickness, chemical milling is usually the most economical method. A formed channel 23 feet long made of 0.125 inch aluminum 7075-T6 had a scalloped edge and recessed pockets and a lengthwise selant groove. Chemical milling with caustic soda allowed production schedules for initial wing-beam units to be met before conventional router tooling could be fabricated, (Ref. 5.14). The metal is immersed in an etching bath which may be acidic or basic, to remove metal from specific areas so as to produce the desired configuration. Finally the maskant is stripped from the part. To produce a simple shape, the masking and milling procedure is only performed once. Complex designs are usually produced by repeating the masking and milling sequence until the desired shape is achieved.

Standard mechanical property tests indicate that chemical milling has appreciable effect on the compression, tension, or shear properties of aluminum alloy 7075, (Ref. 5.11). Fatigue tests on 7075-T6, performed at high stress levels, show more favorable results for chemically-milled material than for machine-milled material.

RELATIVE FORMABILITY OF HEAT-TREATABLE ALLOYS
IN ORDER OF DECREASING FORMABILITY

TABLE 5.1

Source	Ref. 5.2
Rating	Alloy
1	No. 21 and No. 22 (Brazing Sheet)
2	6061
3	6066
4	2024
5	2014
6	$\boxed{7075}$
7	7178

APPROXIMATE BEND RADII FOR 90 DEGREE COLD BEND (a)(c)

TABLE 5.2

Source	Ref. 5.1, pp. 36, 37 and 47												
Temper	F_{tu}, ksi		F_{ty}, ksi		e, (b)	Thickness, t, inches							
-	Min	Max	Min	Max	Min	1/64	1/32	1/16	1/8	3/16	1/4	3/8	1/2
O	-	40	-	21	10	0	0	0-1t	1/2t-1 1/2t	1t-2t	1 1/2t-3t	2 1/2t-4t	3t-5t
T6(d)	77	-	66	-	8	2t-4t	3t-5t	4t-6t	5t-7t	5t-7t	6t-10t	7t-11t	7t-12t

(a) Radii for various thickness expressed in terms of thickness, t.
(b) Elongation, per cent in 2 inch or 4D.
(c) Mechanical properties (F_{tu}, F_{ty}, and e) are minimum or maximum for thickness below 0.200.
(d) Alclad sheet can be bent over slightly smaller radii than the corresponding tempers of the uncoated alloy.

RECOMMENDED MAXIMUM HOLDING TIMES FOR 7075-T6 ALLOY PRIOR TO FORMING, AS A FUNCTION OF HOLDING TEMPERATURE

TABLE 5.3

Source	Ref. 5.4, p. 133
Temp of Hold, F	Time in indicated Units
300	10 - 12 hours
325	2 - 4 hours
350	1 - 2 hours
375	30 - 60 minutes
400	5 - 10 minutes
425	To temp
450	No
500	No

Note: The above guide indicates maximum reheat periods; shorter heating times may give satisfactory results.
Under controlled conditions, strength loss due to reheating will seldom exceed 5 percent.

RELATIVE FORMABILITY OF HEAT-TREATABLE ALLOYS FOR EXTRUSIONS AND TUBES IN ORDER OF DECREASING FORMABILITY

TABLE 5.4

Source	Ref. 5.2, p. 94
Extrusions	Tubes
1. 6063, 6463	1. 6063
2. 6061, 6062	2. 6061, 6062
3. 2024	3. 2024
4. 2014	4. 2014
5. $\boxed{7075}$, 7079	5. $\boxed{7075}$
6. 7178	

HEAT-TREAT TEMPERS FOR HAND FORGINGS

TABLE 5.5

Source	Ref. 5.8, p. 57
Temper	Treatment
F	As forged, no thermal treatment following fabrication operation
W	Solution heat-treated and quenched in water at 140F
T6	Solution heat-treated, quenched in water at 140F and artificially aged
T652	Solution heat-treated, quenched in water at 140F, stress relieved by cold compression artificially aged

Note: Forgings in the T73 temper are also available. This temper is obtained by a proprietary thermal treatment.

MACHINING RECOMMENDATIONS FOR SOLUTION TREATED AND AGED 7075 ALLOY

TABLE 5.6

Source	Ref. 5.9						
Operation	Cutting Conditions*	High Speed Tool Speed fpm	High Speed Tool Feed ipr	High Speed Tool Tool mat'l	Carbide Tool Speed fpm	Carbide Tool Feed ipr	Carbide Tool Tool mat'l
Single point Turning	0.250 inch depth of cut	600	0.015	T1, M1	1100	0.015	C-1
	0.050 inch depth of cut	800	0.008	T1, M1	1400	0.008	C-2
Form tool, turning	0.500 inch form tool width	450	0.0035	T1, M1,	1000	0.0035	C-2
	0.750 inch form tool width	450	0.0035	HSS	1000	0.0035	C-2
	1.000 inch form tool width	450	0.003	HSS	1000	0.003	C-2
	1.500 inch form tool width	450	0.0025	HSS	1000	0.002	C-2
	2.000 inch form tool width	450	0.002	HSS	1000	0.002	C-2
Boring	0.010 inch depth of cut	600	0.008	T1, M1,	1100	0.010	C-1, C-3
	0.050 inch depth of cut	570	0.010	HSS	1050	0.015	C-1, C-3
	0.100 inch depth of cut	540	0.015	HSS	1000	0.020	C-1, C-3
Planing	0.500 inch depth of cut	300	0.060	T1, M1	300	0.060*	C-2
	0.050 inch depth of cut	300	0.050	T1, M1	300	0.050	C-2
	0.010 inch depth of cut	300	3/4**	T1, M1	300	3/4**	C-2
Face milling	0.250 inch depth of cut	800	0.020*	T1, M1	max	0.018*	C-2
	0.050 inch depth of cut	1000	0.022*	T1, M1	max	0.020*	C-2
End milling (Profiling)	3/4 inch cutter diameter	700	0.006*	M1, M10	1200	0.005*	C-2
	1/2 inch cutter diameter	700	0.009*	M1, M10	1200	0.008*	C-2
	1/8 inch cutter diameter	1000	0.0007*	M1, M10	1800	0.0005*	C-2
	3/8 inch cutter diameter	1000	0.005*	M1, M10	1800	0.004*	C-2
	3/4 inch cutter diameter	1000	0.007*	M1, M10	1800	0.006*	C-2
	1 to 2 inch cutter diameter	1000	0.010*	M1, M10	1800	0.009*	C-2
Drilling	1/8 inch nominal hole diameter	250	0.003	M1, M10			
	1/4 inch nominal hole diameter	250	0.007	HSS			
	1/2 inch nominal hole diameter	250	0.012	HSS			
	3/4 inch nominal hole diameter	250	0.016	HSS			
	1 inch nominal hole diameter	250	0.020	HSS			
	1 1/2 inch nominal hole diameter	250	0.025	HSS			
	2 inch nominal hole diameter	250	0.030	HSS			
	3 inch nominal hole diameter	250	0.030	HSS			

* Feed - inches per tooth

** Feed - 3/4 the width of square nose finishing tool

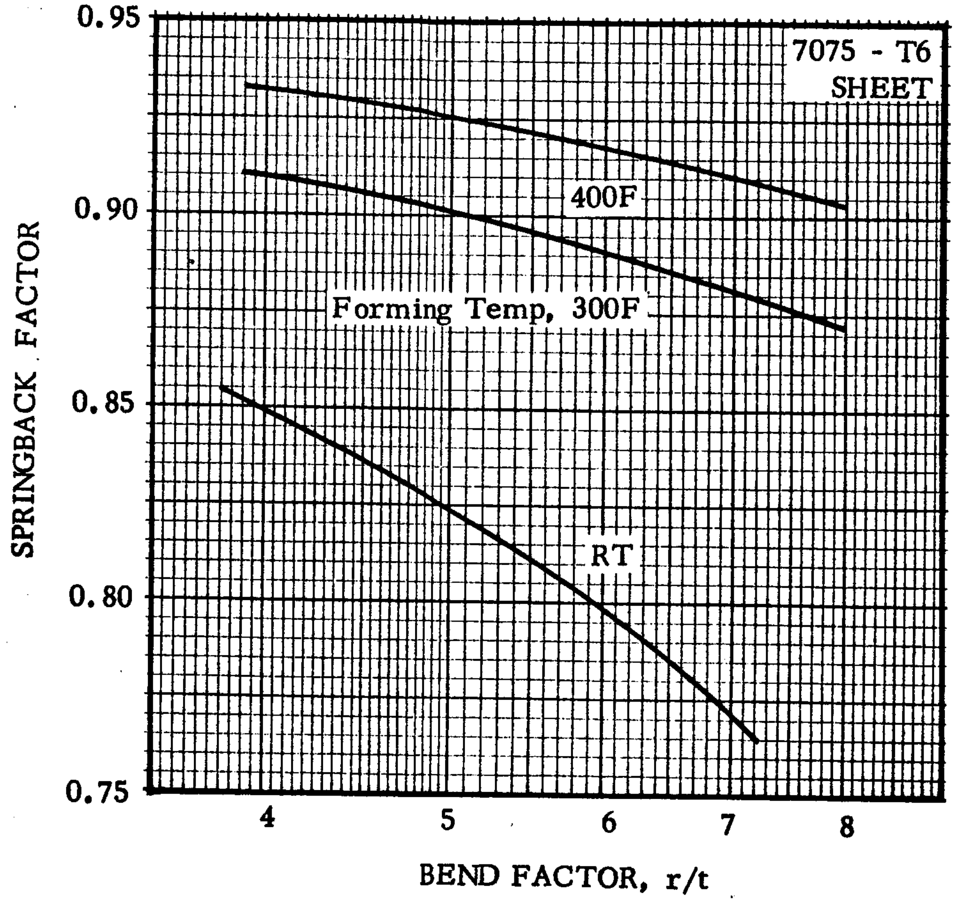


FIG. 5.1 EFFECT OF FORMING TEMPERATURE ON SPRINGBACK OF SHEET IN T6 CONDITION

(Ref. 5.15)

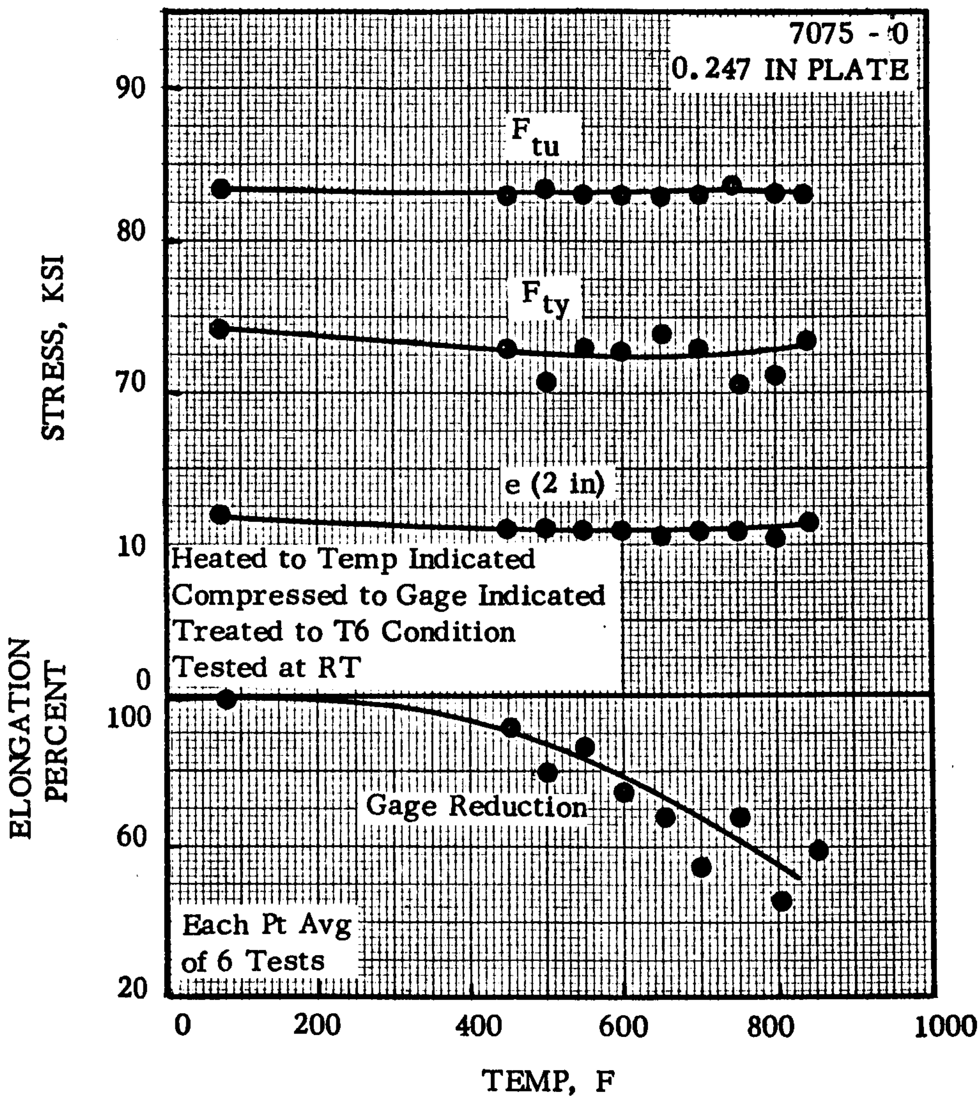


FIG. 5.2 EFFECT OF FORMING AT ELEVATED TEMPERATURES ON ROOM TEMPERATURE TENSILE PROPERTIES OF PLATE IN O CONDITION PRIOR TO FORMING AND T6 CONDITION AFTER FORMING (Ref. 5.16)

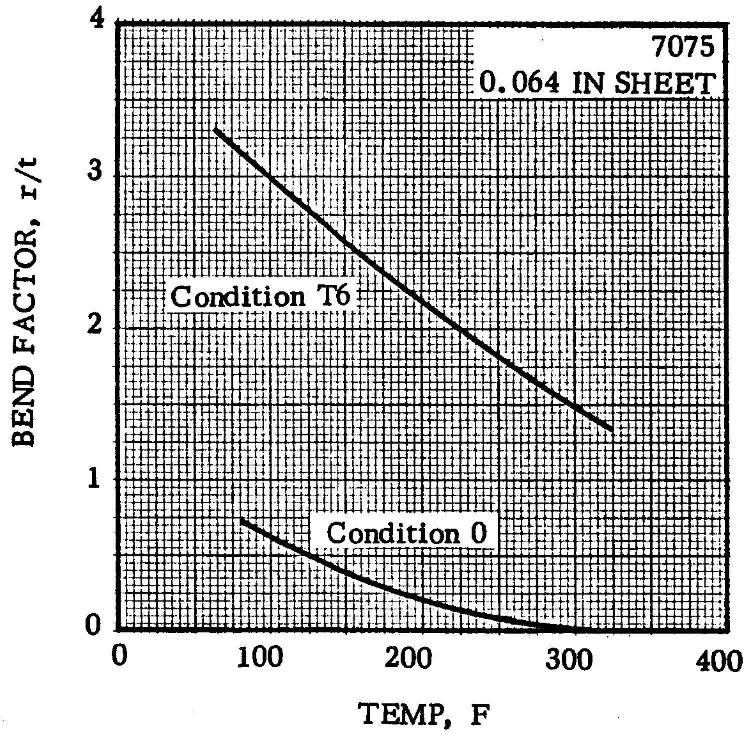


FIG. 5.3 EFFECT OF FORMING TEMPERATURE ON BEND FACTOR IN RUBBER FORMING OF SHEET IN 0 AND T6 CONDITIONS

(Ref. 5.15)

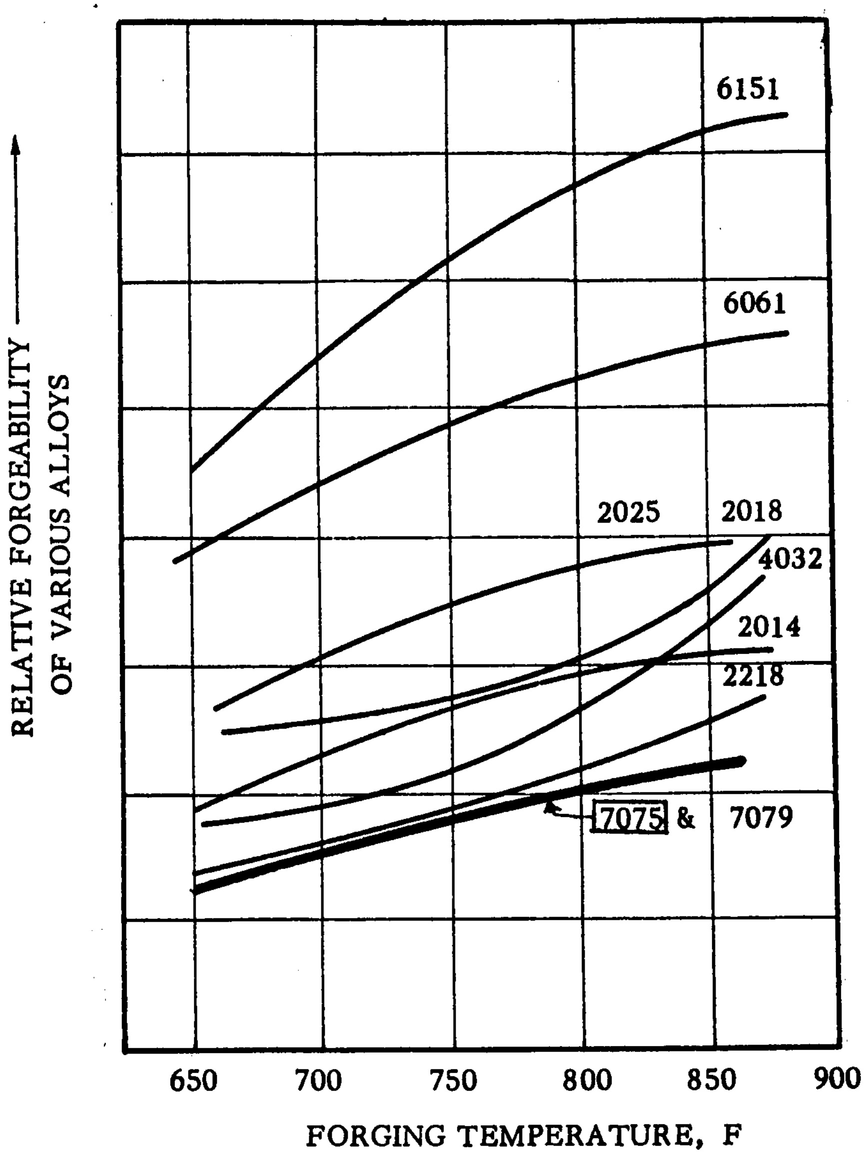


FIG. 5.4 RELATIVE FORGEABILITY OF VARIOUS ALUMINUM ALLOYS

(Ref. 5.8, p. 264)

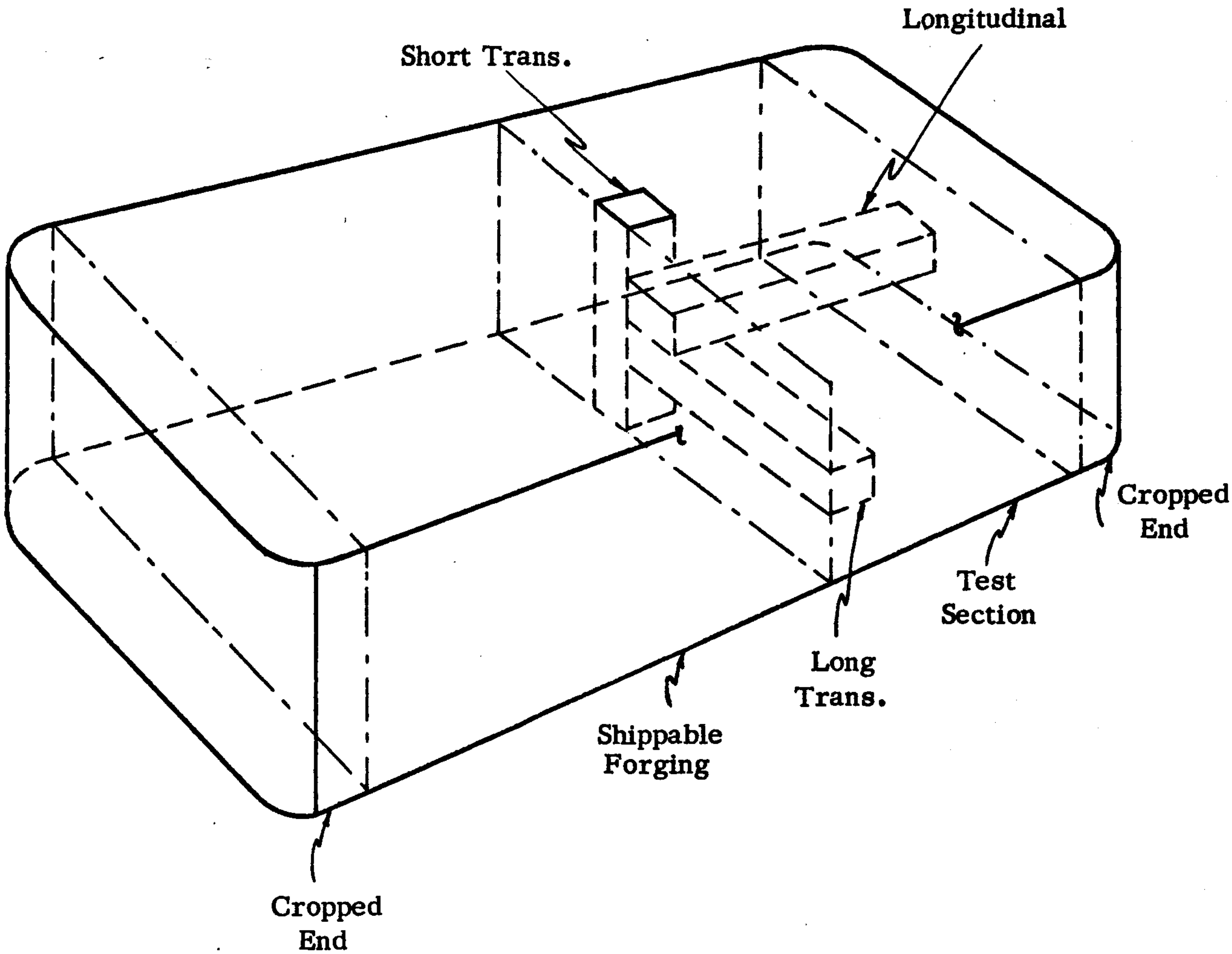


FIG. 5.5 LOCATIONS OF TEST BARS FOR TESTING OF HAND FORGINGS OF RECTANGULAR OR SQUARE CROSS SECTIONS

(Ref. 5.8)

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CHAPTER 6

SPACE ENVIRONMENT EFFECTS

6.1 General. Aluminum alloys have been used in both structural and non-structural applications in launch vehicles and spacecraft with excellent success since, in general, the aluminum alloys are relatively insensitive to degradation in the typical space environmental conditions. The vapor pressures of the structural aluminum alloys are sufficiently high, (Fig. 6.1) so that the combined temperature-vacuum effects generally are negligible. Structural alloys such as 7075 are sufficiently hardened so that nuclear and space indigenous radiation induced defects do not significantly affect mechanical and physical properties, at room ambient and elevated temperatures, below accumulated doses of about 10^{22} particles/cm^2. When irradiated at cryogenic temperatures, the threshold may be lowered one or two decades, but the probabilities of experiencing doses on this order of magnitude are extremely remote except in the vicinity of nuclear reactors.

Elevated temperatures, hard vacuums, high energy radiation, and micrometeoroids can singularly and collectively influence surface characteristics of 7075 by desorption processes and erosion. These phenomena might be of great importance if optical properties, lubrication, certain electrical properties, etc., were critical design parameters.

Sputtering of the surface by atomic or molecular particles can deteriorate surface finishes in a relatively short period. A 300 Å coating of aluminum (10^{-5}gm/cm^2) can be destroyed in one month during a period of low intensity solar wind or in several hours during a solar storm, for example. Threshold energies for sputtering reactions are quite low, in the order of 6, 11, and 12 ev for O, N_2 and O_2 particles, respectively. Estimates of surface erosion by sputtering are given in Tables 6.1 and 6.2 for aluminum alloys.

Micrometeoroids can produce surface erosion similar to sputtering, although perhaps on a more macroscopic scale, as well as punctures. Micrometeoroids vary widely in mass, composition, velocity, and flux; generalizations about the rates of erosion and penetration, therefore, must be used with care. The predicted frequency of impact as a function of meteoroid mass is given in Fig. 6.2. Data are given in Figs. 6.3 and 6.4 on the penetration and cratering of aluminum alloy skins of various thicknesses.

The surface erosion of 7075 due to corpuscular radiation is probably insignificant, amounting to something on the order of 10μ per year. Indigenous space radiation, however, will tend to accelerate the removal of surface films on the 7075. The removal of such films might result in loss of lubricity and an increase propensity to "cold weld". The interaction of indigenous radiation with desorption gases might cause some spurious, transient electrical conditions when 7075 is used for electrical applications. The interaction of indigenous radiation with the 7075 will produce some internal heating that might be significant for small items and some induced radioactivity.

IMPACT FLUX, MASS FLUX, PARTICLE CONCENTRATION, AND DENSITY FOR THE PARTICLE BELT SURROUNDING THE EARTH

TABLE 6.1

Source		Ref. 6.3			
Zone	Altitude[a]	Flux Impact (m^{-2} - sec^{-1})	Flux Mass ($gm\text{-}cm^{-2}\text{-}sec^{-1}$)	Particle Concentration (cm^{-3})	Density ($gm\text{-}cm^{-3}$)
1	100km < h < 400km	10^{-1} to 10^{0}	10^{-13} to 10^{-12}	4×10^{-11} to 4×10^{-10}	4×10^{-19} to 4×10^{-18}
2	400km < h < $2R_E$	10^{-4} to 10^{-2}	10^{-16} to 10^{-14}	4×10^{-14} to 4×10^{-12}	4×10^{-22} to 4×10^{-20}
3	h > $2R_E$	5×10^{-6} to 10^{-4}	5×10^{-18} to 10^{-16}	2×10^{-15} to 4×10^{-14}	2×10^{-23} to 4×10^{-22}
	Zodiacal cloud	2×10^{-6} to 1.2×10^{-3}	10^{-17} to 10^{-15}	10^{-15} to 10^{-13}	3×10^{-23} to 3×10^{-21}

(a) h is distance from earth's surface in km unless given in R_E (earth radii).

ESTIMATED RATE OF REMOVAL AND TIME TO REMOVE 1 Å OF ALUMINUM BY SPUTTERING

TABLE 6.2

Source	Ref. 6.2			
	Orbiting Vehicle		Escaping Vehicle	
Height (Km)	Rate (atom cm^{-2} sec^{-1})	Time (sec/Å)	Rate (atom cm^{-2} sec^{-1})	Time (sec/Å)
100	3.1×10^{16}	1.9×10^{-2}	3.4×10^{17}	1.8×10^{-3}
220	2.0×10^{13}	30	2.0×10^{17}	3.0×10^{-3}
700	2.2×10^{9}	2.7×10^{5}	3.4×10^{11}	1.8×10^{3}
2500	4.3×10^{5}	1.4×10^{9}	1.6×10^{8}	3.8×10^{6}

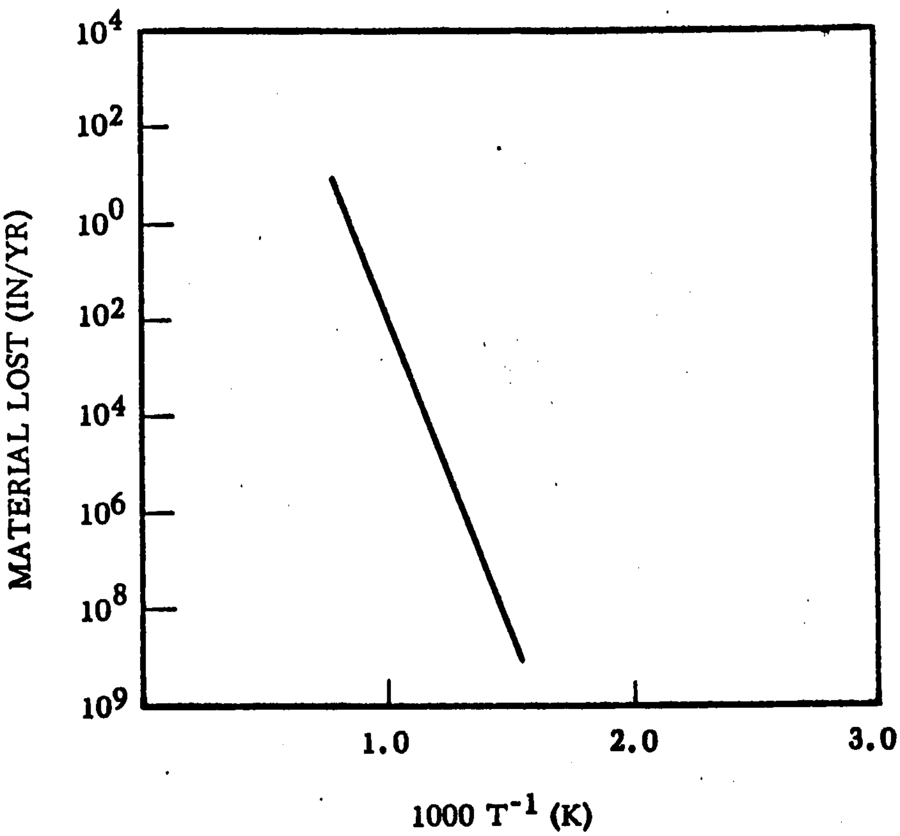

FIG. 6.1 EVAPORATION RATE FOR ALUMINUM
(Ref. 6.1)

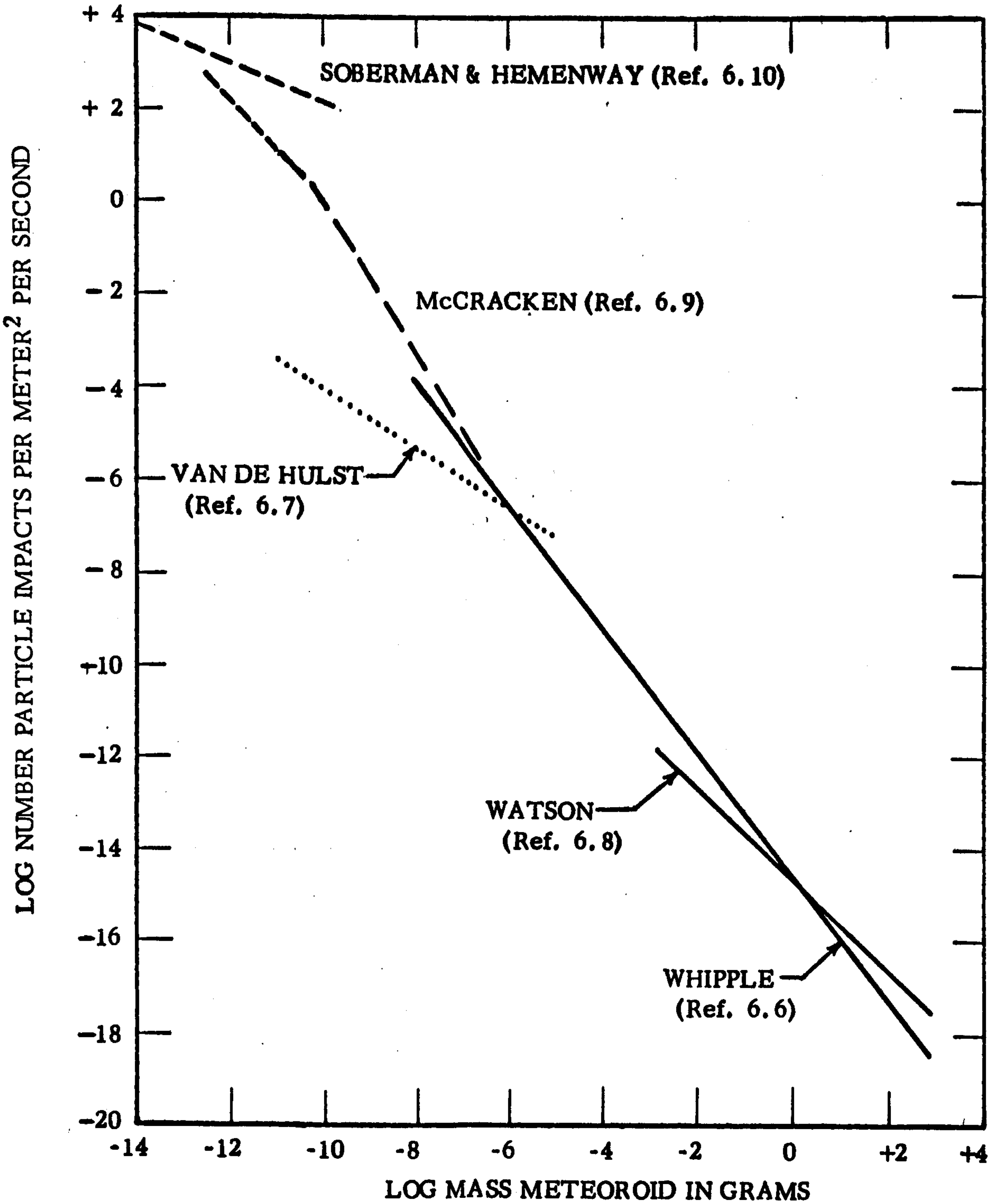

FIG. 6.2 CUMULATIVE METEOROID IMPACT RATES NEAR THE EARTH (Ref. 6.1)

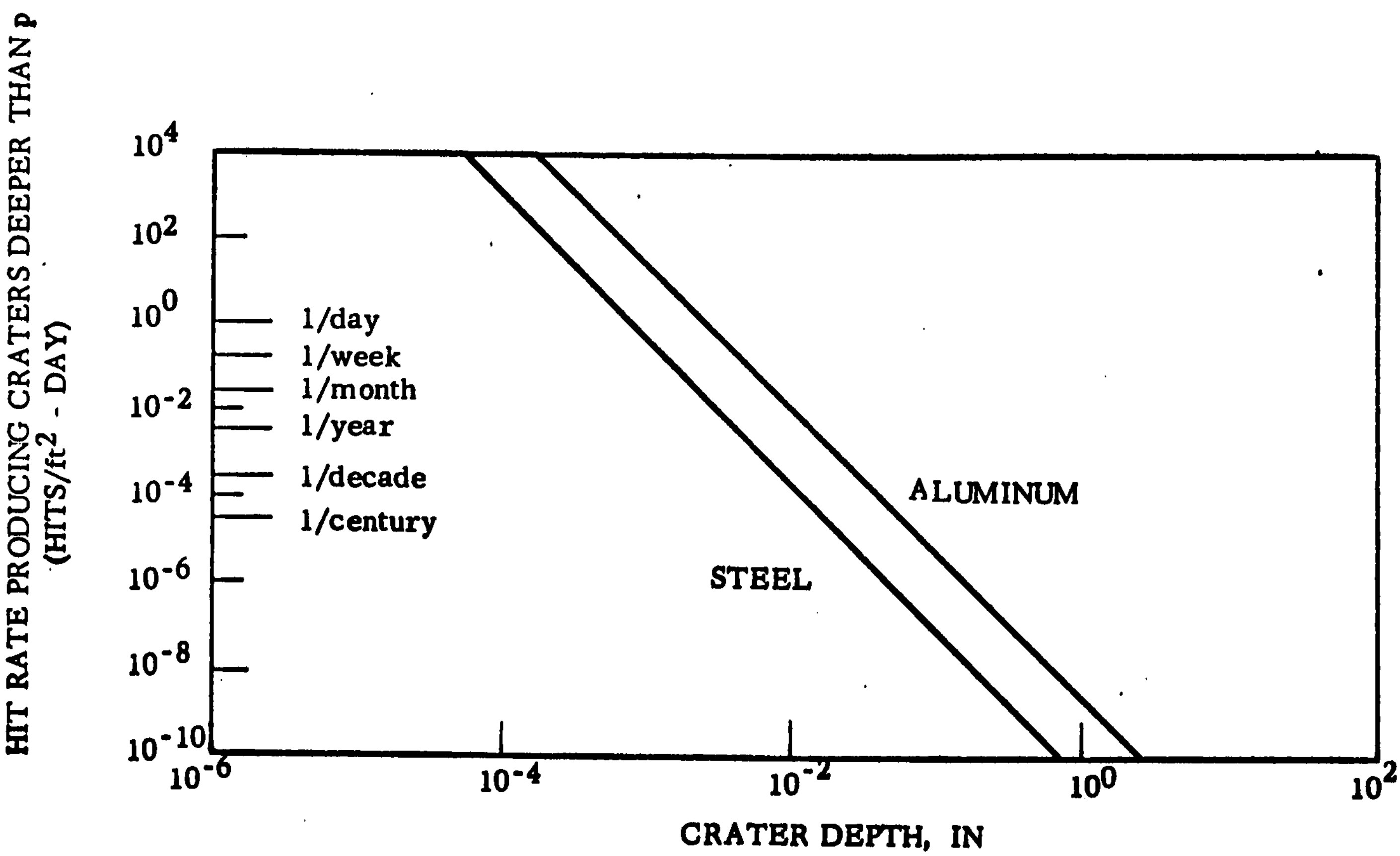

FIG. 6.3 HIT RATE vs CRATER DEPTH IN THE EARTH NEIGHBORHOOD BUT WITHOUT EARTH SHIELDING

(Ref. 6.4)

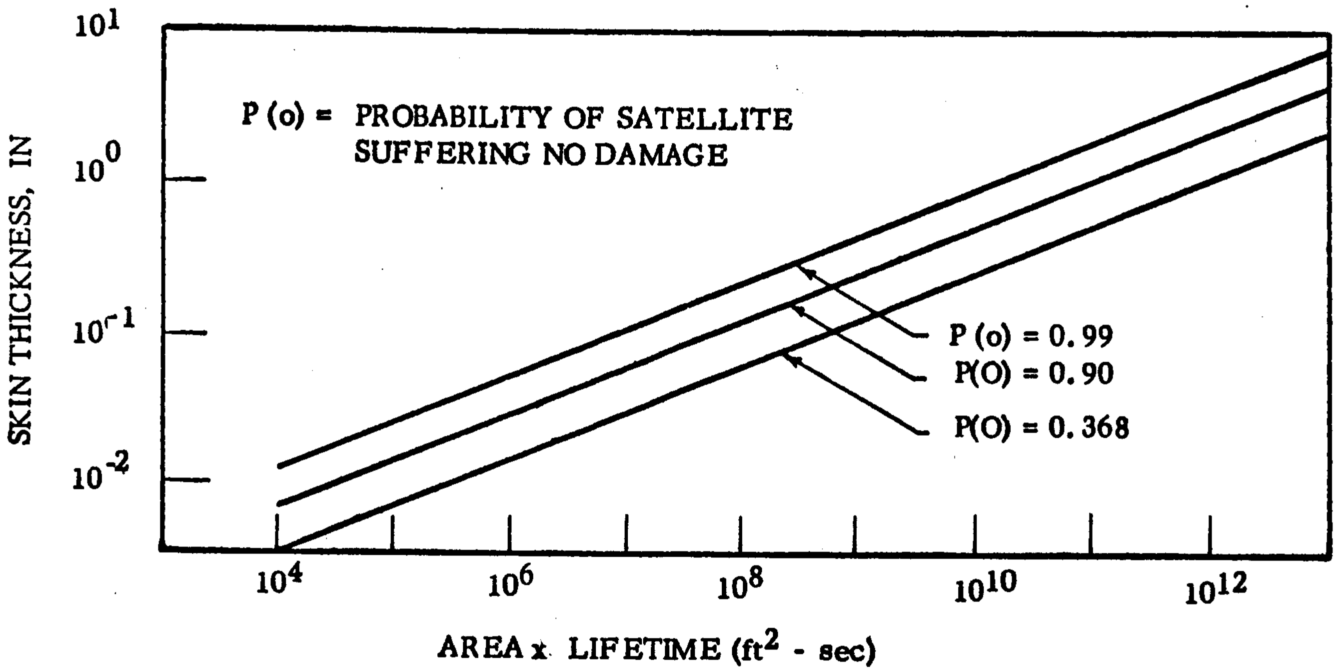

FIG. 6.4 ALUMINUM SKIN THICKNESS REQUIRED FOR METEOROID PROTECTION (Ref. 6.5)

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CHAPTER 7

STATIC MECHANICAL PROPERTIES

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7.112 NASA specified mechanical properties for hand forgings, Table 7.112.

7.113 NASA specified mechanical properties for T652 hand forgings, Table 7.113.

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7.12 AMS Specified Properties

7.121 AMS specified properties are given in detail in Ref. 7.1.

7.13 Military Specified Properties

7.14 Federal Specified Properties

7.15 ASTM Specified Properties

7.151 ASTM specified properties are given in the 1965 ASTM Book of Standards, Part 6, (Ref. 7.2).

7.16 Aluminum Association Mechanical Property Limits

7.161 Aluminum Association mechanical property limits are given in the Aluminum Association "Standards for Aluminum Mill Products", (Ref. 7.3).

7.2 Elastic Properties and Moduli

7.21 Poisson's ratio. 0.33, (Ref. 7.4).

7.22 Young's modulus of elasticity, E.

7.221 Design value of E. All products and tempers, $E = 10.3 \times 10^3$ ksi, (Ref. 7.5).

7.222 Typical value of E. 10.4×10^3 ksi, (Ref. 7.6).

7.223 Effect of temperature on E and E_c for alloy in T6 Condition, Fig. 7.223.

7.224 Effect of low temperatures on E, Fig. 7.224.

7.225 Modulus of elasticity at various temperatures, Fig. 7.225.

7.23 Compression modulus, E_c.

7.231 Design value of E_c. All products and tempers, $E_c = 10.5 \times 10^3$ ksi, (Ref. 7.5).

7.232 Effect of temperature on E_c, see Fig. 7.223.

7.24 Modulus of rigidity (shear modulus), G.

7.241 Design value of G. 3.9×10^3 ksi, (Ref. 7.5).

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7.251 Tangent modulus curves in compression for bar and extrusions in T6 Condition at room temperature, Fig. 7.251.

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7.32 Effect of low temperature on hardness of bar, Fig. 7.32.

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7.4135 Effect of low temperatures on tensile properties of sheet and plate in T6 Condition, Fig. 7.4135.

7.42 Compression

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7.4214 Design compression properties for Clad T6 sheet and T651 plate, see Table 7.4114.

7.4215 Design compression properties for Clad plate in T6 temper, see Table 7.4115.

7.4216 Design compression properties for hand forged stock and die forgings, see Table 7.4116.

7.4217 Design compression properties for extrusions in various tempers, see Table 7.4117.

7.422 Stress-strain diagrams (compression)

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7.4231 Effect of exposure and test temperature on compressive yield strength of sheet in T6 Condition, Fig. 7.4231.

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7.44 Shear and torsion

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7.4613 Effect of low temperatures on notch strength of T6 sheet, Fig. 7.4613.

7.462 Fracture toughness

7.4621 Net fracture stress and fracture toughness of sheet at elevated temperatures, Fig. 7.4621.

NASA SPECIFIED MECHANICAL PROPERTIES FOR DIE FORGINGS AND SEPARATELY FORGED TEST BARS

TABLE 7.111

Alloy	7075 (b)			
Specification	NASA-MSFC-SPEC-144B			
Product	Die Forgings and Separately Forged Test Bars			
Max sect. thick, in	3			
Temper	T6		T73	
Orientation	A	B	A	B
F_{tu}, min-ksi (a)	75.0	71.0	66.0	62.0
F_{ty}, min-ksi (a)	65.0	62.0	56.0	53.0
e(2 in or 4D)min-percent	7	3	7	3

A Test specimen parallel to forging flow lines.

B Test specimen not parallel to forging flow lines (die forgings only).

(a) Tensile and yield strength test requirements may be waived for material in any direction in which the dimension is less than 2 inches because of the difficulty in obtaining a tension test specimen suitable for routine control testing.

(b) Die forgings in some configurations of this alloy can be purchased in the T652 temper conforming to the mechanical property requirements specified for the T6 temper.

NASA SPECIFIED MECHANICAL PROPERTIES FOR T6 HAND FORGINGS

TABLE 7.112

Alloy	7075-T6			
Specification	NASA - MSFC - SPEC - 144B			
Product	Hand Forgings (a)			
Thickness, in (b)	Axis of test Specimen	F_{tu}, ksi min, (c)	F_{ty}, ksi min, (c)	e(2 in or 4D) min, percent
≤ 2.000	L	74.0	63.0	9
	LT	73.0	61.0	4
2.001-3.000	L	73.0	61.0	9
	LT	71.0	59.0	4
	ST	69.0	58.0	3
3.001-4.000	L	71.0	60.0	8
	LT	70.0	58.0	3
	ST	68.0	57.0	2
4.001-5.000	L	69.0	58.0	7
	LT	68.0	56.0	3
	ST	66.0	56.0	2
5.001-6.000	L	68.0	56.0	6
	LT	66.0	55.0	3
	ST	65.0	55.0	2

(a) Maximum cross-sectional area is 256 square inches.
(b) Thickness is measured in the short transverse direction and applies to the "as forged" dimension before machining.
(c) Tensile property requirements may be waived for directions in which the dimension is less than 2 inches.

NASA SPECIFIED MECHANICAL PROPERTIES OF T652 HAND FORGINGS

TABLE 7.113

Alloy	7075-T652			
Specification	NASA - MSFC - SPEC - 144B			
Product	Hand Forgings (a)			
Thickness, in (b)	Axis of test Specimen	F_{tu}, ksi min, (c)	F_{ty}, ksi min, (c)	e(2 in or 4 D) min, percent
≤ 2.000	L	74.0	63.0	9
	LT	73.0	61.0	4
2.001-3.000	L	73.0	61.0	9
	LT	71.0	59.0	4
	ST	69.0	57.0	2
3.001-4.000	L	71.0	60.0	8
	LT	70.0	58.0	3
	ST	68.0	56.0	2
4.001-5.000	L	69.0	58.0	6
	LT	68.0	56.0	3
	ST	66.0	55.0	1
5.001-6.000	L	68.0	56.0	6
	LT	66.0	55.0	3
	ST	65.0	54.0	1

(a) Maximum cross-sectional area is 256 square inches.
(b) Thickness is measured in the short transverse direction and applies to the "as forged" dimension before machining.
(c) Tensile property requirements may be waived for directions in which the dimension is less than 2 inches.

NASA SPECIFIED MECHANICAL PROPERTIES FOR T73 HAND FORGINGS

TABLE 7.114

Alloy	7075-T73			
Specification	NASA-MSFC-SPEC-144B			
Product	Hand Forgings (a)			
Thickness, in (b)	Axis of test Specimen	F_{tu}, ksi min, (c)	F_{ty}, ksi (min, (c)	e(2 in or 4D) min, percent
≤ 3.000	L	66.0	56.0	7
	LT	64.0	54.0	4
	ST	61.0	52.0	3

(a) Maximum cross-sectional area is 256 square inches.

(b) Thickness is measured in the short transverse direction and applies to the "as forged" dimension before machining.

(c) Tensile property requirements may be waived for directions in which the dimension is less than 2 inches.

DESIGN MECHANICAL PROPERTIES FOR BAR, ROD, WIRE AND SHAPES IN VARIOUS TEMPERS

TABLE 7.4111

Alloy	QQ-A-225/9 (7075)									
Form	Bar, rod, wire and shapes, rolled, drawn or cold-finished									
Condition	—T6 or —T651				—T7351					
Thickness, in	Up to 1.000 [a]	1.001–2.000 [a]	2.001–3.000 [a]	3.001–4.000 [a]	0.375–1.000		1.001–2.000		2.001–3.000	
Basis	A	A	A	A	A	B	A	B	A	B
Mechanical properties:										
F_{tu}, ksi:										
L	77	77	77	77	66	69	66	69	66	69
LT	77	75	72	69	......	......	......	......	64	67
F_{ty}, ksi:										
L	66	66	66	66	56	60	56	60	56	60
LT	66	66	63	60	......	......	......	......	52	56
F_{cy}, ksi:										
L	64	64	64	64	53	57	54	58	54	58
LT	......	......	......	......	......	......	......	......	53	57
F_{su}, ksi	46	46	46	46	40	42	40	42	40	42
F_{bru}, ksi:										
$(e/D=1.5)$	100	100	100	100	86	90	86	90	86	90
$(e/D=2.0)$	123	123	123	123	106	110	106	110	106	110
F_{bry}, ksi:										
$(e/D=1.5)$	86	86	86	86	73	78	73	78	73	78
$(e/D=2.0)$	92	92	92	92	78	84	78	84	78	84
e, percent:										
L	[b] 7	7	7	7	10	......	10	......	10	......
LT	4	3	2	1	......	......	......	......	......	......

[a] For rounds (rod) maximum diameter is 4 in.; for square bar, maximum size is 3½ x 3½ in.; for rectangular bar, maximum thickness is 3 in. with corresponding width of 6 in.; for rectangular bar less than 3 in. in thickness, maximum width is 10 in.

[b] Except for wire less than 0.125 in. in diameter.

(Ref. 7.5)

DESIGN MECHANICAL PROPERTIES FOR T6 SHEET AND T651 PLATE

TABLE 7.4112

Alloy	QQ-A-250/12 (7075)																	
Form	Sheet				Plate													
Condition	-T6				-T651													
Thickness, in.	0.015–0.039		0.040–0.249		0.250–0.499		0.500–1.000		1.001–2.000		2.001–2.500		2.501–3.000		3.001–3.500		3.500–4.000	
Basis	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Mechanical properties:																		
F_{tu}, ksi																		
L	76	78	77	79	76	78	76	78	76	78	72	74	69	71	69	71	66	68
LT	76	78	77	79	77	79	77	79	77	79	73	75	70	72	70	72	67	69
ST	...	...	...	...	...	...	...	...	...	...	65	67	63	65	63	65	60	62
F_{ty}, ksi																		
L	66	69	67	70	68	70	68	70	68	70	64	66	62	64	59	61	55	57
LT	65	68	66	69	66	68	66	68	66	68	62	64	60	62	57	59	53	55
ST	...	...	...	...	...	...	...	...	...	...	55	57	53	55	51	53	47	49
F_{cy}, ksi																		
L	67	70	68	71	67	69	66	68	65	67	60	62	58	60	55	57	50	52
LT	70	73	71	74	70	72	70	72	70	72	66	68	64	66	60	62	56	58
ST	...	...	...	...	...	...	...	...	...	...	63	65	61	63	58	60	54	56
F_{su}, ksi	46	47	46	47	43	44	44	45	45	46	43	44	42	43	42	44	41	42
F_{bru}, ksi (a)																		
(e/D=1.5)	114	117	116	119	117	120	117	120	117	120	111	114	106	109	106	109	102	105
(e/D=2.0)	144	148	146	150	144	148	144	148	144	148	136	140	131	135	131	135	125	129
F_{bry}, ksi (a)																		
(e/D=1.5)	92	97	94	98	97	100	98	101	100	103	96	99	94	97	91	94	86	89
(e/D=2.0)	106	110	107	112	114	117	115	118	117	121	112	116	110	113	106	109	99	103
e, percent																		
L	7	...	8	...	8	...	6	...	5	...	5	...	5	...	5	...	...	...
LT	7	...	8	...	8	...	6	...	4	...	3	...	3	...	3	...	2	...
ST	...	...	...	...	...	...	...	...	...	...	1	...	1	...	1	...	...	...

(a) See Table 7.452.

(Ref. 7.5)

DESIGN MECHANICAL PROPERTIES FOR T6 PLATE

TABLE 7.4113

Alloy	QQ-A-250/12 (7075)											
Form	Plate											
Condition	-T6											
Thickness, in	0.250–0.499		0.500–1.000		1.001–2.000		2.001–2.500		2.501–3.000		3.001–3.500	3.501–4.000
Basis	A	B	A	B	A	B	A	B	A	B	S	S
Mechanical properties:												
F_{tu}, ksi												
L	77	79	79	82	78	80	73	75	70	72	70	67
LT	77	79	77	80	77	79	73	75	70	72	70	67
ST	...	...	...	...	...	...	67	69	64	66	64	61
F_{ty}, ksi												
L	67	69	69	72	68	71	62	65	60	62	57	53
LT	66	68	66	69	66	69	62	65	60	62	57	53
ST	...	...	...	...	...	...	61	63	59	60	55	51
F_{cy}, ksi												
L	69	71	69	72	68	71	65	67	63	65	61	57
LT	69	71	69	72	68	71	65	67	63	65	61	57
ST	...	...	...	...	...	...	64	66	62	63	61	57
F_{su}, ksi	46	47	47	49	46	47	43	45	41	43	41	40
F_{bru}, ksi (a)												
($e/D=1.5$)	108	110	110	115	109	112	102	105	98	101	98	94
($e/D=2.0$)	139	142	142	147	140	144	131	135	126	130	126	121
F_{bry}, ksi (a)												
($e/D=1.5$)	87	90	90	94	88	92	81	84	78	81	74	69
($e/D=2.0$)	100	104	104	108	102	106	93	97	90	93	85	79
e, percent												
L	8	...	6	...	5	...	5	...	5	...	5	...
LT	8	...	6	...	4	...	3	...	3	...	3	2
ST	...	...	...	...	...	...	1	...	1	...	1	...

(a) See Table 7.452.

(Ref. 7.5)

DESIGN MECHANICAL PROPERTIES FOR CLAD T6 SHEET AND T651 PLATE

TABLE 7.4114

Alloy	QQ-A-250/13 (Clad 7075)							
Form	Sheet							
Condition	-T6							
Thickness, in	0.012–0.039		0.040–0.062		0.063–0.187		0.188–0.249	
Basis	A	B	A	B	A	B	A	B
Mechanical properties:								
F_{tu}, ksi								
L	70	73	72	74	73	75	75	77
LT	70	73	72	74	73	75	75	77
ST	...	...	...	...	...	...	...	...
F_{ty}, ksi								
L	61	64	63	65	64	66	65	67
LT	60	63	62	64	63	65	64	66
ST	...	...	...	...	...	...	...	...
F_{cy}, ksi								
L	62	65	64	66	65	67	66	68
LT	64	67	66	68	67	69	68	70
ST	...	...	...	...	...	...	...	...
F_{su}, ksi	42	44	43	44	44	45	45	46
F_{bru}, ksi [a]								
(e/D=1.5)	105	110	108	111	110	112	112	116
(e/D=2.0)	133	139	137	141	139	142	142	146
F_{bry}, ksi [a]								
(e/D=1.5)	85	90	88	91	90	92	91	94
(e/D=2.0)	98	102	101	104	102	106	104	107
e, percent								
L	7	...	8	...	8	...	8	...
LT	7	...	8	...	8	...	8	...
ST	...	...	...	...	...	...	...	...

Alloy	QQ-A-250/13 (Clad 7075)													
Form	Plate													
Condition	-T651													
Thickness, in	0.250–0.499		0.500–1.000 [b]		1.001–2.000 [b]		2.001–2.500 [b]		2.501–3.000 [b]		3.001–3.500 [b]		3.501–4.000 [b]	
Basis	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Mechanical properties:														
F_{tu}, ksi														
L	74	76	74	76	74	76	70	72	67	69	67	69	64	66
LT	75	77	75	77	75	77	71	73	68	70	68	70	65	67
ST	...	...	...	...	...	...	65	67	63	65	63	65	60	62
F_{ty}, ksi														
L	66	68	66	68	66	68	62	64	60	62	57	59	53	55
LT	64	66	64	66	64	66	60	62	58	60	55	57	51	53
ST	...	...	...	...	...	...	55	57	53	55	51	53	47	49
F_{cy}, ksi														
L	65	67	64	66	63	65	58	60	56	58	53	55	48	50
LT	68	70	68	70	68	70	64	66	62	64	58	60	54	56
ST	...	...	...	...	...	...	63	65	61	63	58	60	54	56
F_{su}, ksi	42	43	43	44	43	45	42	43	41	42	41	42	40	41
F_{bru}, ksi [a]														
(e/D=1.5)	114	117	114	117	114	117	108	111	103	106	103	106	99	102
(e/D=2.0)	140	144	140	144	140	144	133	136	127	131	127	131	121	125
F_{bry}, ksi [a]														
(e/D=1.5)	94	97	95	98	97	100	93	96	91	94	88	91	82	86
(e/D=2.0)	110	114	111	115	113	117	108	112	106	110	102	106	96	99
e, percent														
L	8	...	6	...	5	...	5	...	5	...	5	...	...	...
LT	8	...	6	...	4	...	3	...	3	...	3	...	2	...
ST	...	...	...	...	...	...	1	...	1	...	1	...	...	...

(a) See Table 7.452.

(b) These values, except in the ST direction, have been adjusted to represent the average properties across the whole section, including the 1 1/2 percent per side nominal cladding thickness.

(Ref. 7.5)

DESIGN MECHANICAL PROPERTIES FOR CLAD PLATE IN T6 TEMPER

TABLE 7.4115

Alloy	QQ-A-250/13 (Clad 7075)											
Form	Plate											
Condition	-T6											
Thickness, in	0.250–0.499		0.500–1.000 [b]		1.001–2.000 [b]		2.001–2.500 [b]		2.501–3.000 [b]		3.001–3.500 [b]	3.501–4.000 [b]
Basis	A	B	A	B	A	B	A	B	A	B	S	S
Mechanical properties												
F_{tu}, ksi												
L	75	77	77	79	76	78	71	73	68	70	63	65
LT	75	77	75	77	75	77	71	73	68	70	68	65
ST	....	....	....	....	....	....	67	69	64	66	64	61
F_{ty}, ksi												
L	65	67	66	68	66	69	60	62	58	60	55	51
LT	64	66	64	66	64	67	60	62	58	60	55	51
ST	....	....	....	....	....	....	61	63	59	60	53	49
F_{cy}, ksi												
L	66	69	66	69	66	69	62	64	61	62	59	55
LT	66	69	66	69	66	69	62	64	61	62	59	55
ST	....	....	....	....	....	....	64	66	62	63	59	55
F_{su}, ksi	45	46	46	47	45	46	42	43	40	41	40	38
F_{bru}, ksi [a]												
($e/D=1.5$)	105	108	108	111	106	109	99	102	95	98	95	91
($e/D=2.0$)	135	139	139	142	137	140	128	131	122	126	122	117
F_{bry}, ksi [a]												
($e/D=1.5$)	84	87	86	88	86	90	78	81	75	78	71	66
($e/D=2.0$)	98	100	99	102	99	104	90	93	87	90	82	76
e, percent												
L	8	....	6	....	5	....	5	....	5	....	5	....
LT	8	....	6	....	4	....	3	....	3	....	3	2
ST	....	....	....	....	....	....	1	....	1	....	1	....

(a) See Table 7.452.
(b) These values, except in the ST direction, have been adjusted to represent the average properties across the whole section, including the 1 1/2 percent per side nominal cladding thickness.

(Ref. 7.5)

TABLE 7.4116

Alloy	7075							
Form	Hand-forged stock, length ≤3 times width			Hand-forged stock, length >3 times width			Die forgings	
Condition	-T6 (a)						-T6	-T73
Thickness, in	...						≤3	≤3
Cross-sectional area, in.^{2}	≤16	>16, ≤33	>36, ≤144	≤16	>16, ≤36	>36, ≤144	...	...
Basis	A	A	A	A	A	A	A	A
Mechanical properties:								
F_{tu}, ksi								
L	75	73	71	75	73	71	75	66
T	75	71	69	73	71	69	71	61
ST	72	68	66	70	68	66	...	...
F_{ty}, ksi								
L	64	61	60	63	60	59	65	56
T	63	60	58	61	59	57	62	52
ST	63	60	58	61	59	57	...	...
F_{cy}, ksi								
L	64	61	60	63	60	59	65	56
T	63	60	58	61	59	57	58	50
ST	...	...	...	...	...	...	...	...
F_{su}, ksi	45	44	43	45	44	43	45	40
F_{bru}, ksi								
(e/D=1.5)	97	95	85	97	95	85	...	86
(e/D=2.0)	135	124	114	135	124	114	...	119
F_{bry}, ksi								
(e/D=1.5)	90	79	78	88	78	77	...	78
(e/D=2.0)	96	91	90	94	90	88	...	84
e, percent								
L	9	7	4	9	7	4	7	7
T	4	3	2	4	3	2	3	3
ST	2	2	1	2	2	1	...	...

(a) Design mechanical properties apply only to sections heat treated in thickness of 3 inches or less.

(Ref. 7.5)

DESIGN MECHANICAL PROPERTIES FOR EXTRUSIONS IN VARIOUS TEMPERS

TABLE 7.4117

Alloy	QQ-A-200/11 (7075)															
Form	Extrusions (rod, bars, and shapes)															
Condition	−T6 [a], −T6510 [b], and −T6511 [b]															
Cross-sectional area, in.²	≲20										≲20		>20, ≲32		≲32	
Thickness [c] (in.)	Up to 0.249		0.250–0.499		0.500–0.749		0.750–1.499		1.500–2.999		3.000–4.499				4.500–5.000	
Basis	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Mechanical properties:																
F_{tu}, ksi																
L	78	82	81	85	81	85	81	85	81	85	81	84	78	81	78	81
LT	76	78	77	79	73	75	72	74	66	68	66	68	65	67	64	66
F_{ty}, ksi																
L	70	74	73	77	72	76	72	76	72	76	71	74	70	73	68	71
LT	64	67	66	68	63	66	62	64	57	59	56	58	55	57	54	56
F_{cy}, ksi																
L	71	75	74	78	[a] 72	[a] 76	[a] 71	[a] 75	[a] 70	[a] 73	66	[a] 69	[a] 66	[a] 69	65	.....
LT	71	75	74	78	73	77	72	75	69	72	65	68	.....	.....	.....	.....
F_{su}, ksi	43	45	45	47	45	47	45	47	45	47	45	46	43	44	43	44
F_{bru}, ksi																
(e/D=1.5)	101	107	97	102	97	102	97	102	97	102	97	101	94	97	94	97
(e/D=2.0)	125	131	130	136	130	136	130	136	130	136	122	126	117	125	117	125
F_{bry}, ksi																
(e/D=1.5)	91	96	80	85	79	84	79	84	79	84	78	81	77	80	75	78
(e/D=2.0)	98	104	102	108	101	106	101	106	101	106	92	96	91	95	88	92
e, percent																
L	7	8	7	8	7	8	7	8	7	8	7	8	6	.....	6	.....
LT	5	.....	5	.....	4	.....	3	.....	1	.....	1	.....	1	.....	1	.....

[a] For temper −T6, all of the above values apply with the exception of F_{cy} (L) for which the values are as follows:

Thickness (in.)	Area (sq. in.)	Direction of test	F_{cy} (A values)	F_{cy} (B values)
0.500–0.749	Up through 20	L	73	77
0.750–1.499	Up through 20	L	72	76
1.500–2.999	Up through 20	L	72	75
3.000–4.499	Up through 20	L	72	75
3.000–4.499	Over 20 through 32	L	68	72

[b] Tempers −T6510 and −T6511 are available commercially only in thicknesses of 0.500 inch and over.

[c] For extrusions with outstanding legs, the load carrying ability of such legs ~~shall~~ be determined on the basis of the properties in the appropriate column corresponding to the leg thickness.

(Ref. 7.5)

SHEET AND PLATE BEARING FACTORS (a)

TABLE 7.4518

Source	Ref. 7.5							
Basis	A Values				B Values			
Thickness, in	K (Ultimate)		K (Yield)		K (Ultimate)		K (Yield)	
	e/D=2.0	e/D=1.5	e/D=2.0	e/D=1.5	e/D=2.0	e/D=1.5	e/D=2.0	e/D=1.5
7075-T6								
0.016-0.039	1.44	1.14	1.06	0.92	1.48	1.17	1.10	0.97
0.040-0.249	1.49	1.16	1.07	0.94	1.50	1.19	1.12	0.98
0.063-0.488	1.39	1.08	1.00	0.87	1.42	1.10	1.04	0.90
0.500-1.000	1.42	1.10	1.04	0.90	1.47	1.15	1.08	0.94
Clad 7075-T6								
0.015-0.039	1.33	1.05	0.98	0.85	1.39	1.10	1.02	0.90
0.040-0.062	1.37	1.08	1.01	0.88	1.41	1.11	1.04	0.91
0.063-0.187	1.39	1.10	1.02	0.90	1.42	1.12	1.06	0.92
0.188-0.249	1.42	1.12	1.04	0.91	1.46	1.16	1.07	0.94
0.250-0.499	1.35	1.05	0.98	0.84	1.39	1.08	1.00	0.87
0.500-1.000	1.39	1.08	0.99	0.86	1.42	1.11	1.02	0.88

(a) For e/D values between 1.5 and 2.0, bearing factors may be obtained by linear interpolation (e = edge distance; D = hole diameter).

(b) K = ratio of actual bearing strength to 100 ksi.

BEARING PROPERTY REDUCTIONS FOR THICK PLATE

TABLE 7.452

Source	Ref. 7.5	
	Bearing Property Reduction, Percent	
Thickness, in	1.001-3.000	3.001-4.000
F_{bru}, (e/D = 1.5)	20	15
(e/D = 2.0)	20	15
F_{bry}, (e/D = 1.5)	5	0
(e/D = 2.0)	5	0

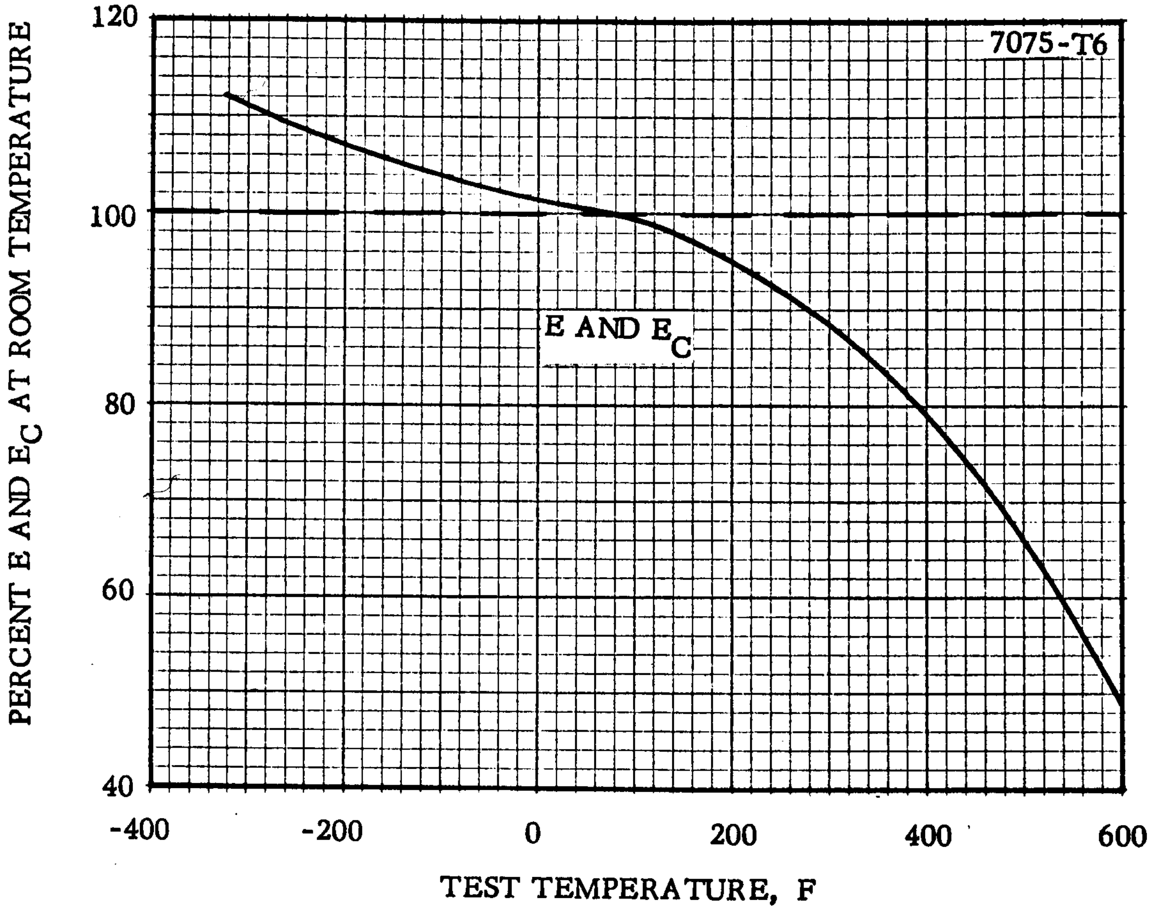

FIG. 7.223 EFFECT OF TEMPERATURE ON E AND E_C FOR ALLOY IN T6 CONDITION

(Ref. 7.5)

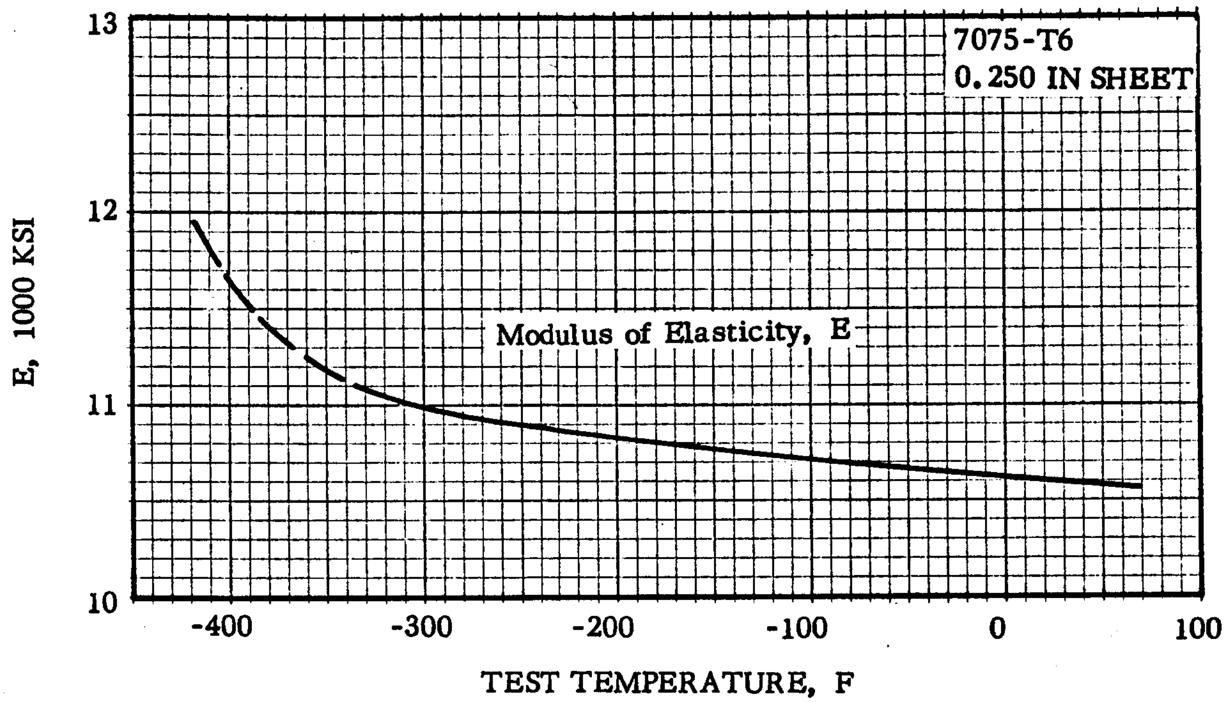

FIG. 7.224 EFFECT OF LOW TEMPERATURES ON E

(Ref. 7.7)

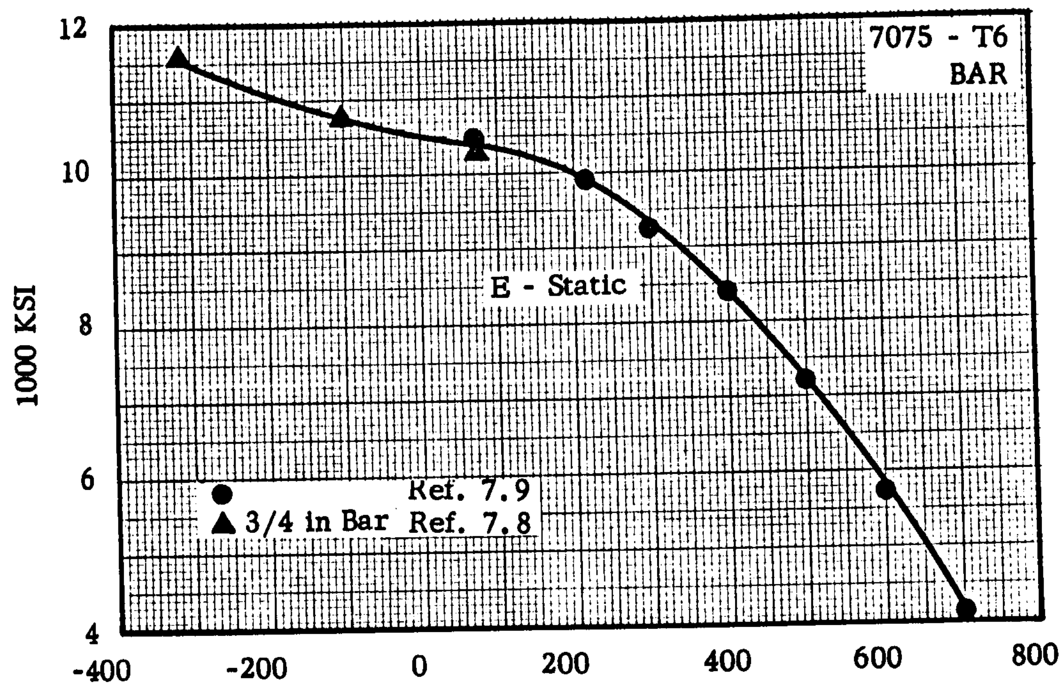

FIG. 7.225 MODULUS OF ELASTICITY AT VARIOUS TEMPERATURES

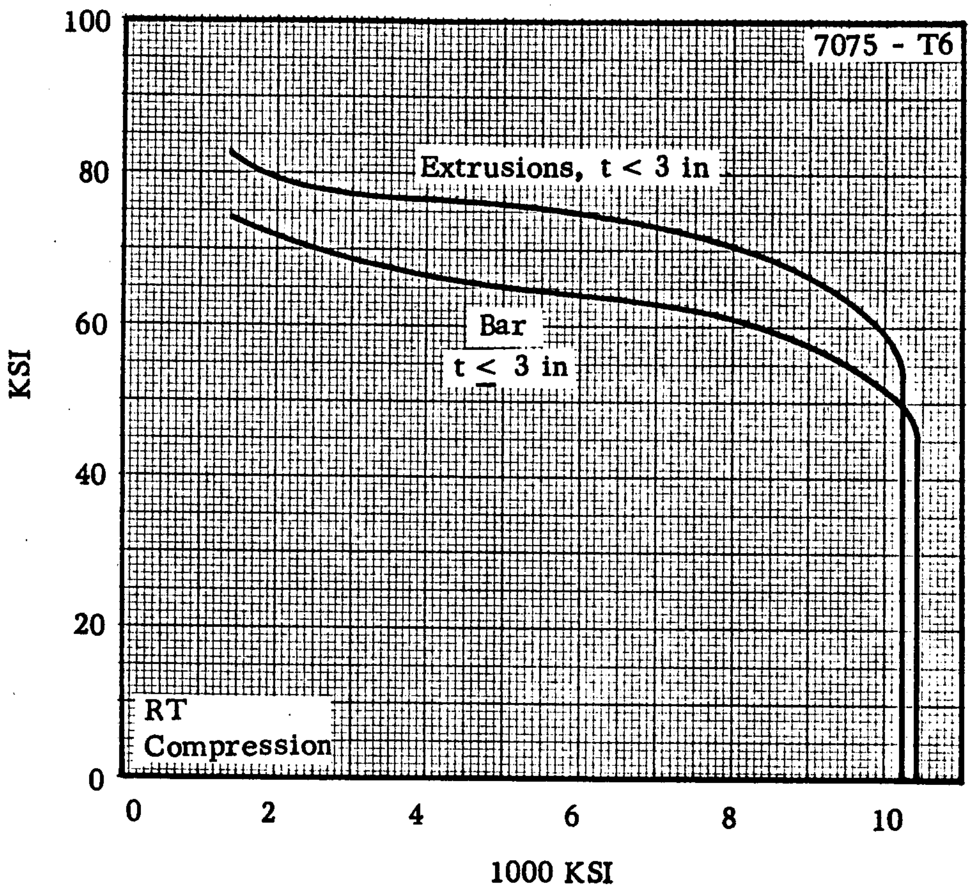

FIG. 7.251 TANGENT MODULUS CURVES IN COMPRESSION FOR ROLLED BAR, ROD, SHAPES AND EXTRUSIONS IN T6 CONDITION AT ROOM TEMPERATURE

(Ref. 7.5)

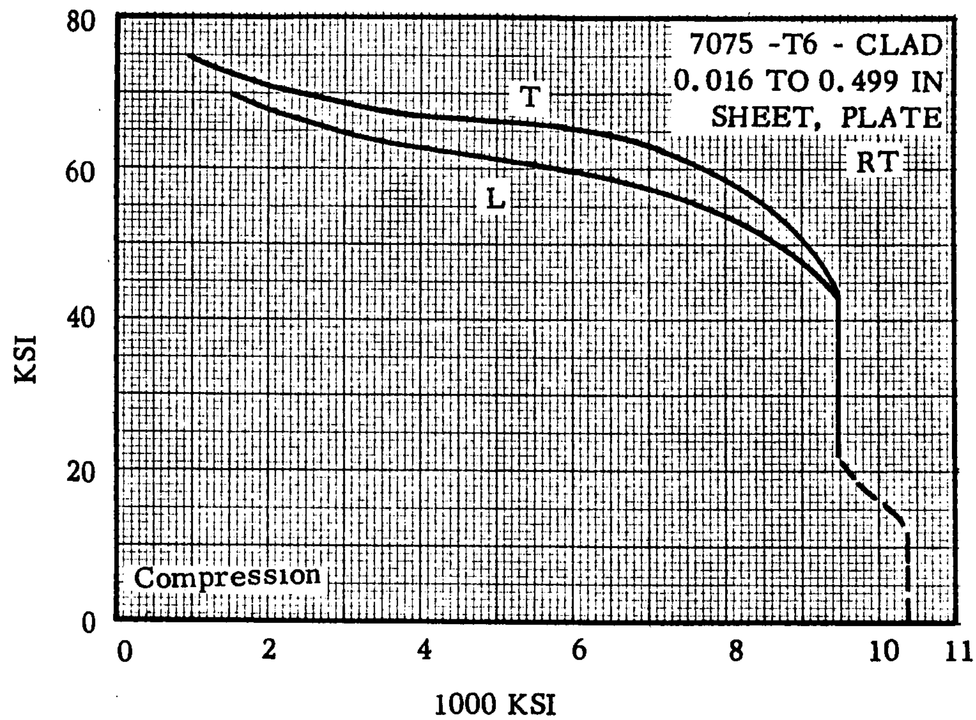

FIG. 7.252 TANGENT MODULUS CURVES IN COMPRESSION FOR SHEET AND PLATE IN T6 CONDITION AT ROOM TEMPERATURE (Ref. 7.5)

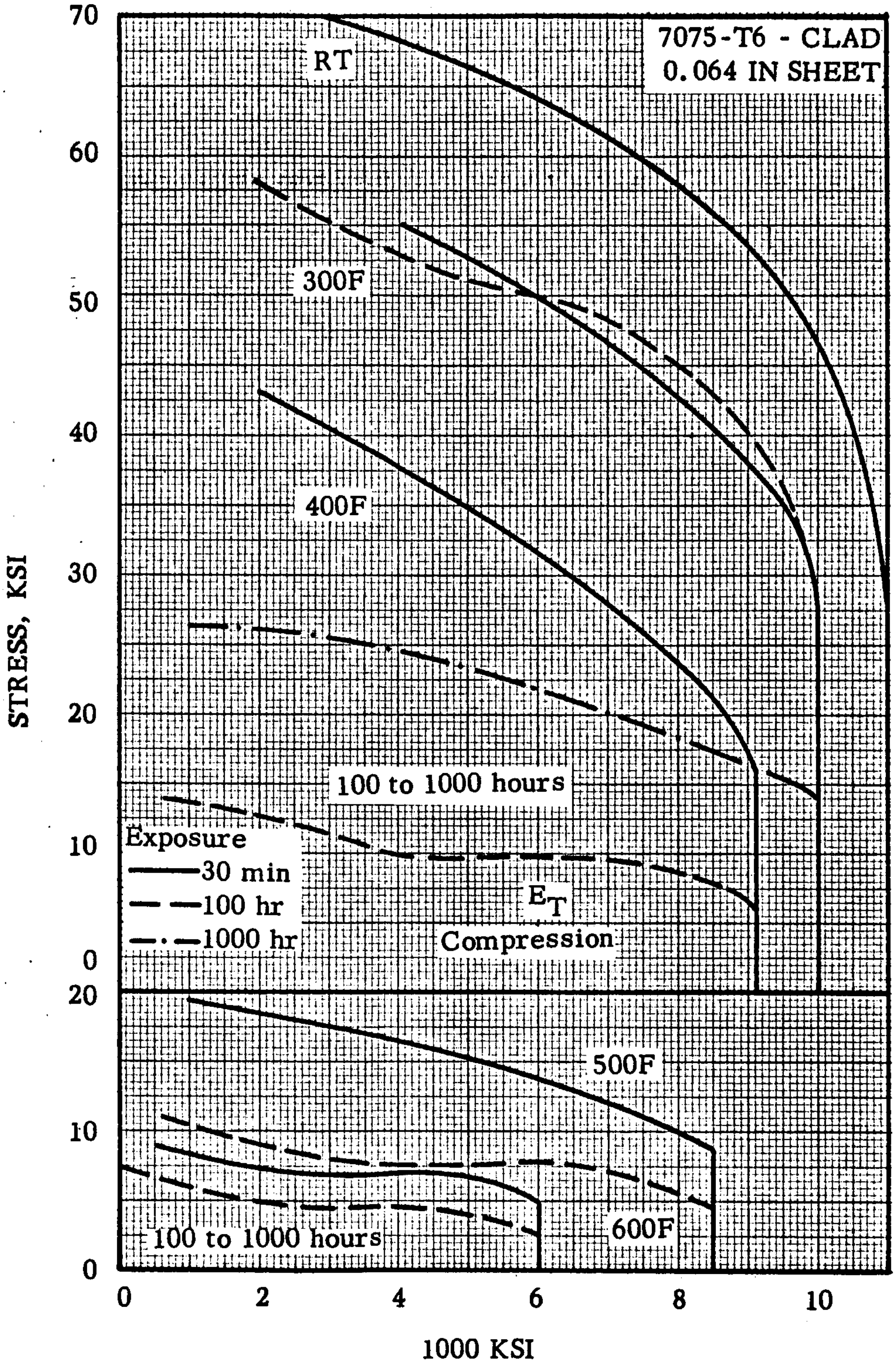

FIG. 7.253 TANGENT MODULUS CURVES IN COMPRESSION FOR SHEET IN T6 CONDITION AT ROOM AND ELEVATED TEMPERATURES (Ref. 7.10)

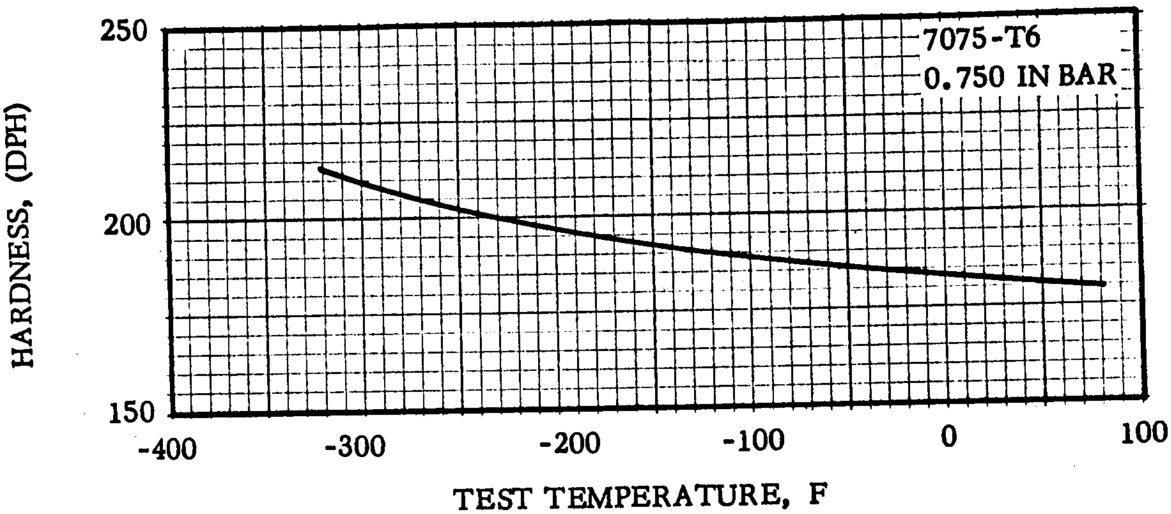

FIG. 7.32 EFFECT OF LOW TEMPERATURES ON HARDNESS OF BAR (Ref. 7.11)

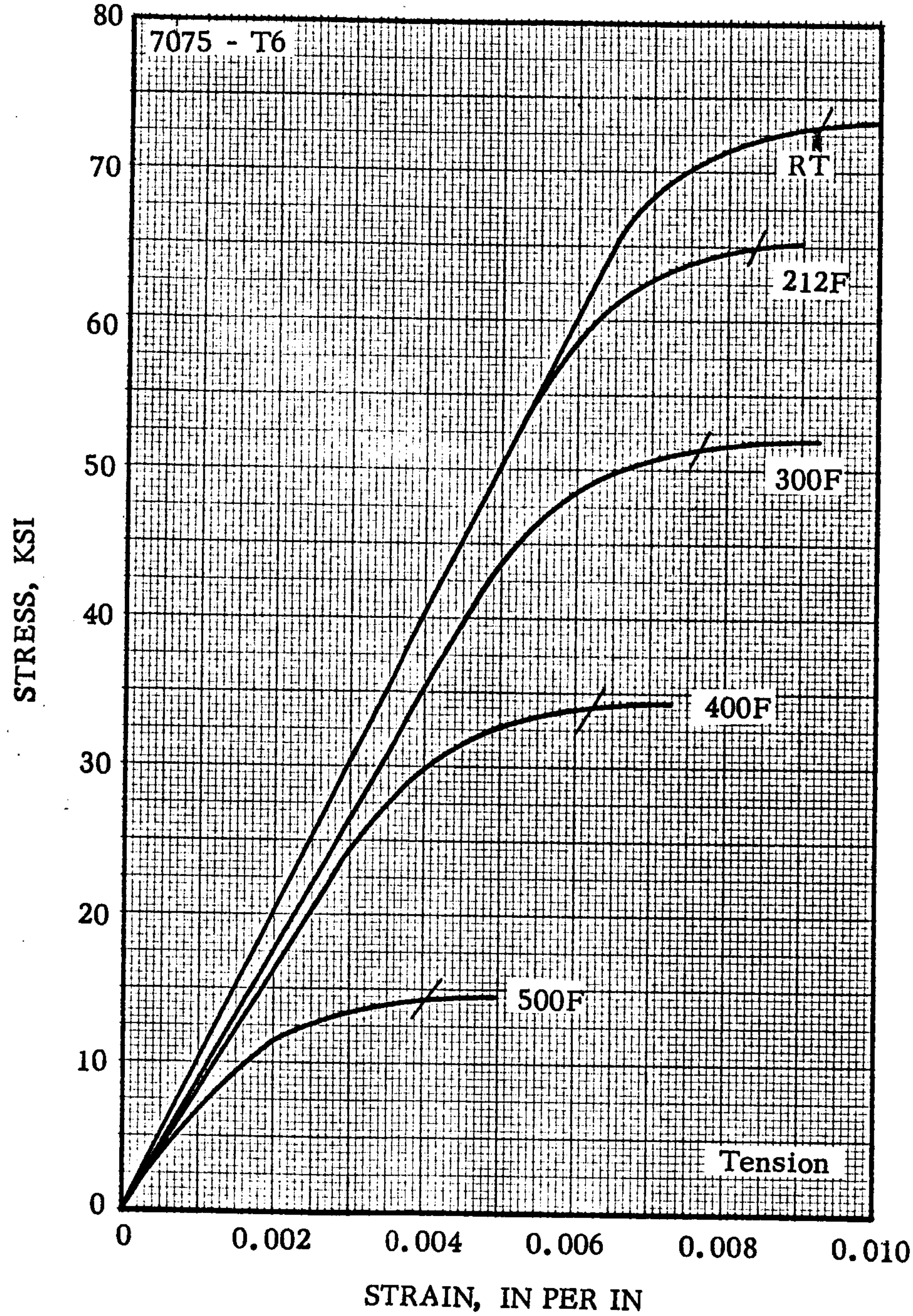

FIG. 7.4121 STRESS-STRAIN CURVES FOR ALLOY IN T6 CONDITION AT ROOM AND ELEVATED TEMPERATURES

(Ref. 7.12)

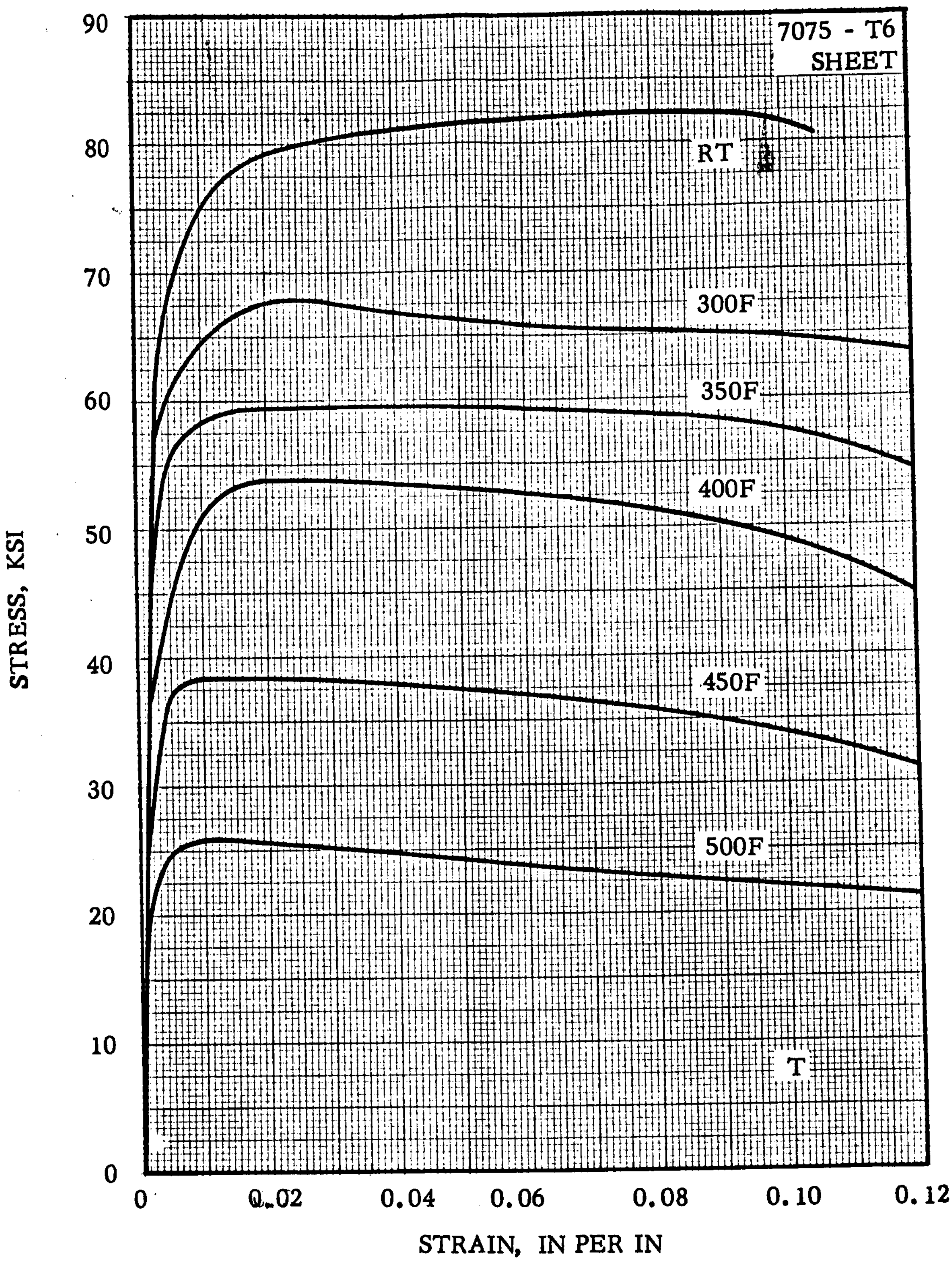

FIG. 7.4122 COMPLETE STRESS-STRAIN CURVES FOR SHEET IN T6 CONDITION AT ROOM AND ELEVATED TEMPERATURES

(Ref. 7.13)

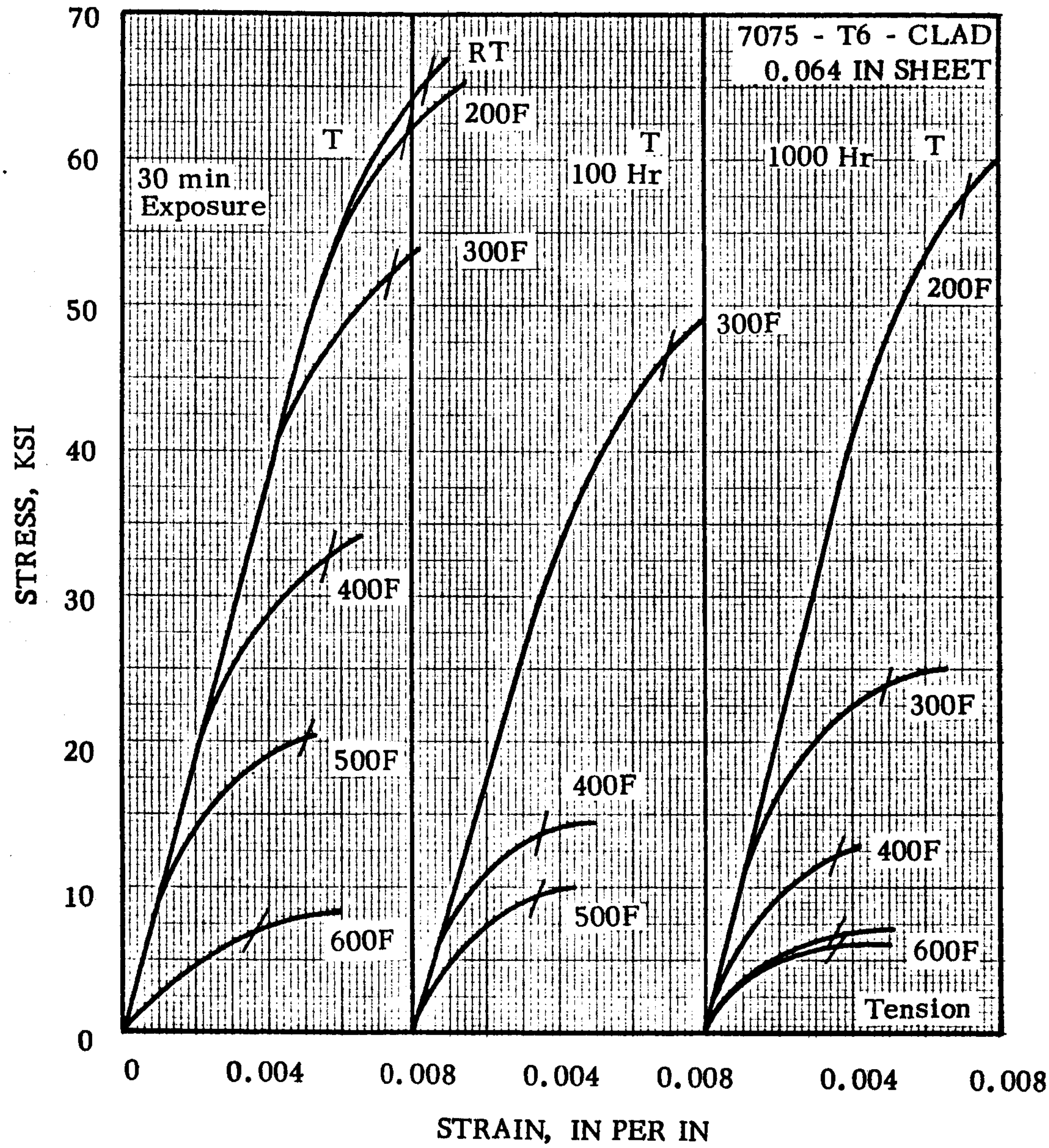

FIG. 7.4123 STRESS-STRAIN CURVES FOR SHEET IN T6 CONDITION AT ROOM AND ELEVATED TEMPERATURES

(Ref. 7.10)

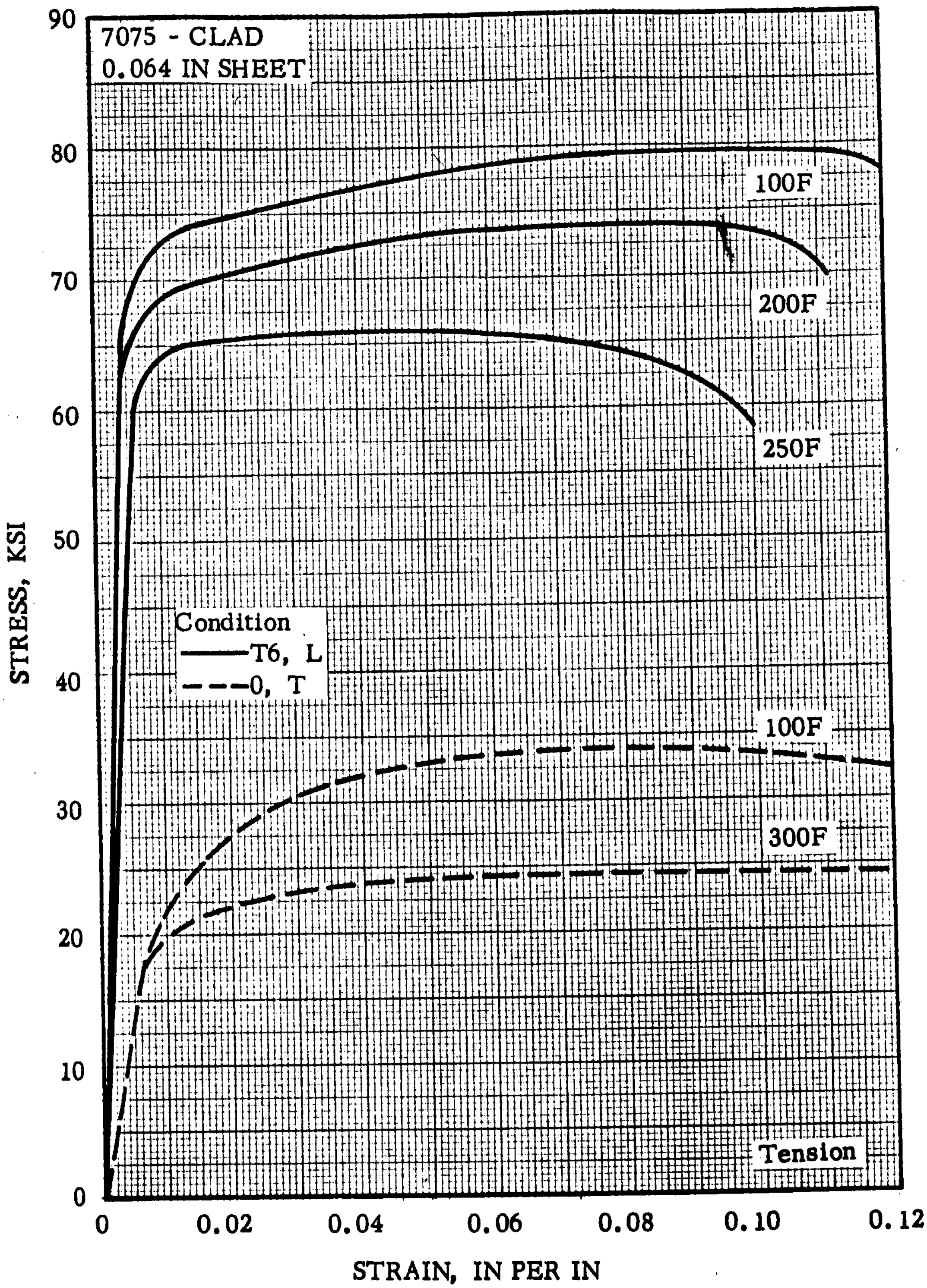

FIG. 7.4124 COMPLETE STRESS-STRAIN CURVES FOR SHEET IN 0 AND T6 CONDITIONS AT ROOM AND ELEVATED TEMPERATURES (Ref. 7.13)

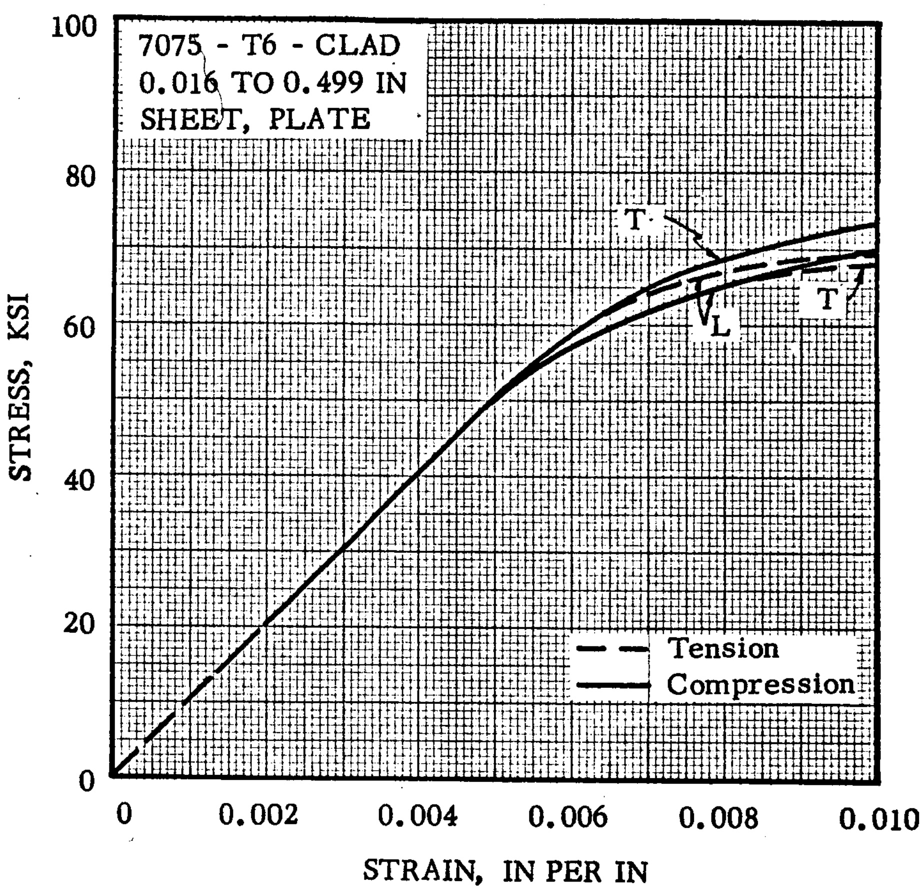

FIG. 7.4125 EFFECT OF DIRECTIONALITY AND STRESS-STRAIN CURVES FOR SHEET AND PLATE IN T6 CONDITION

(Ref. 7.5)

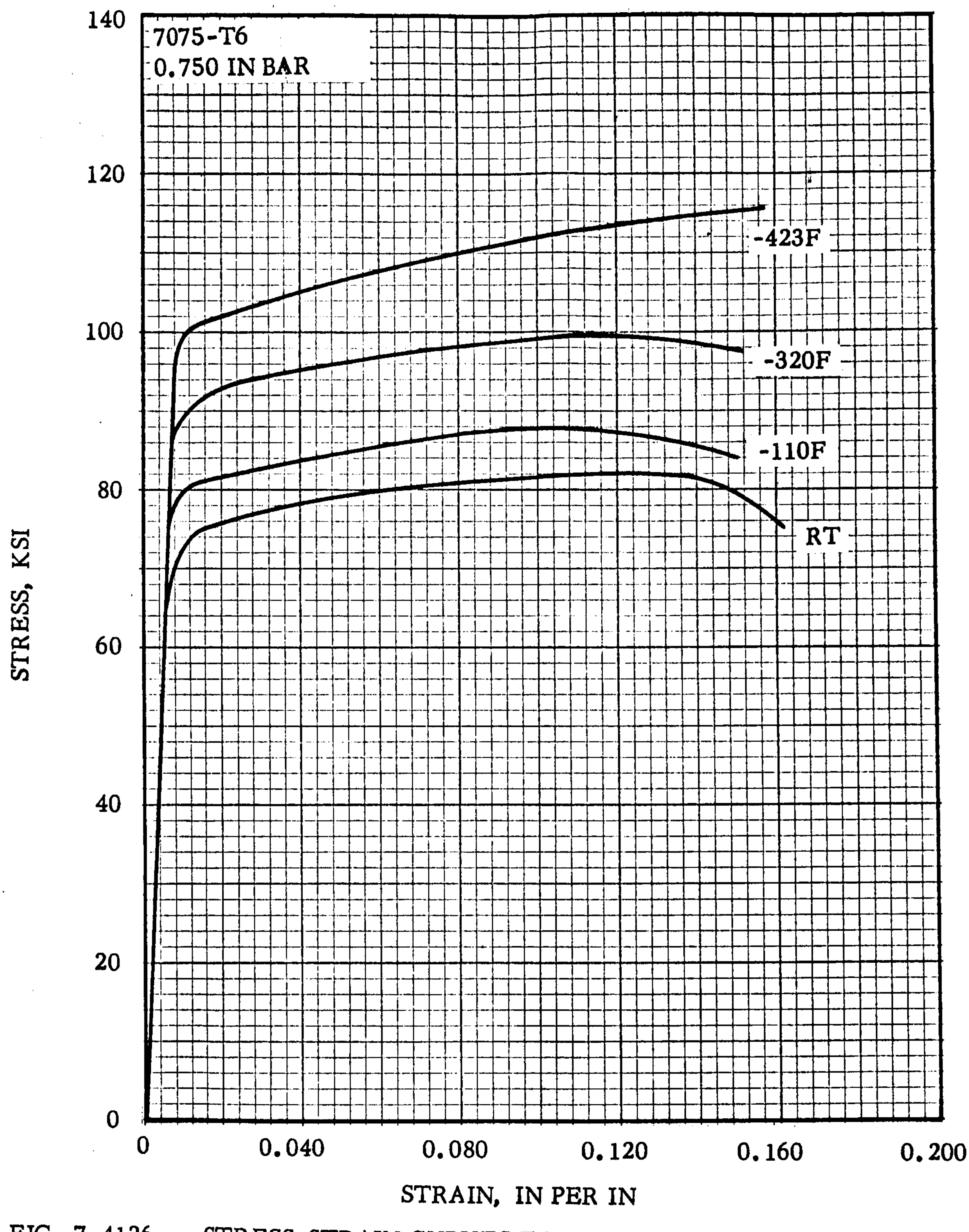

FIG. 7.4126 STRESS-STRAIN CURVES FOR BAR IN T6 CONDITION AT LOW TEMPERATURES

(Ref. 7.14)

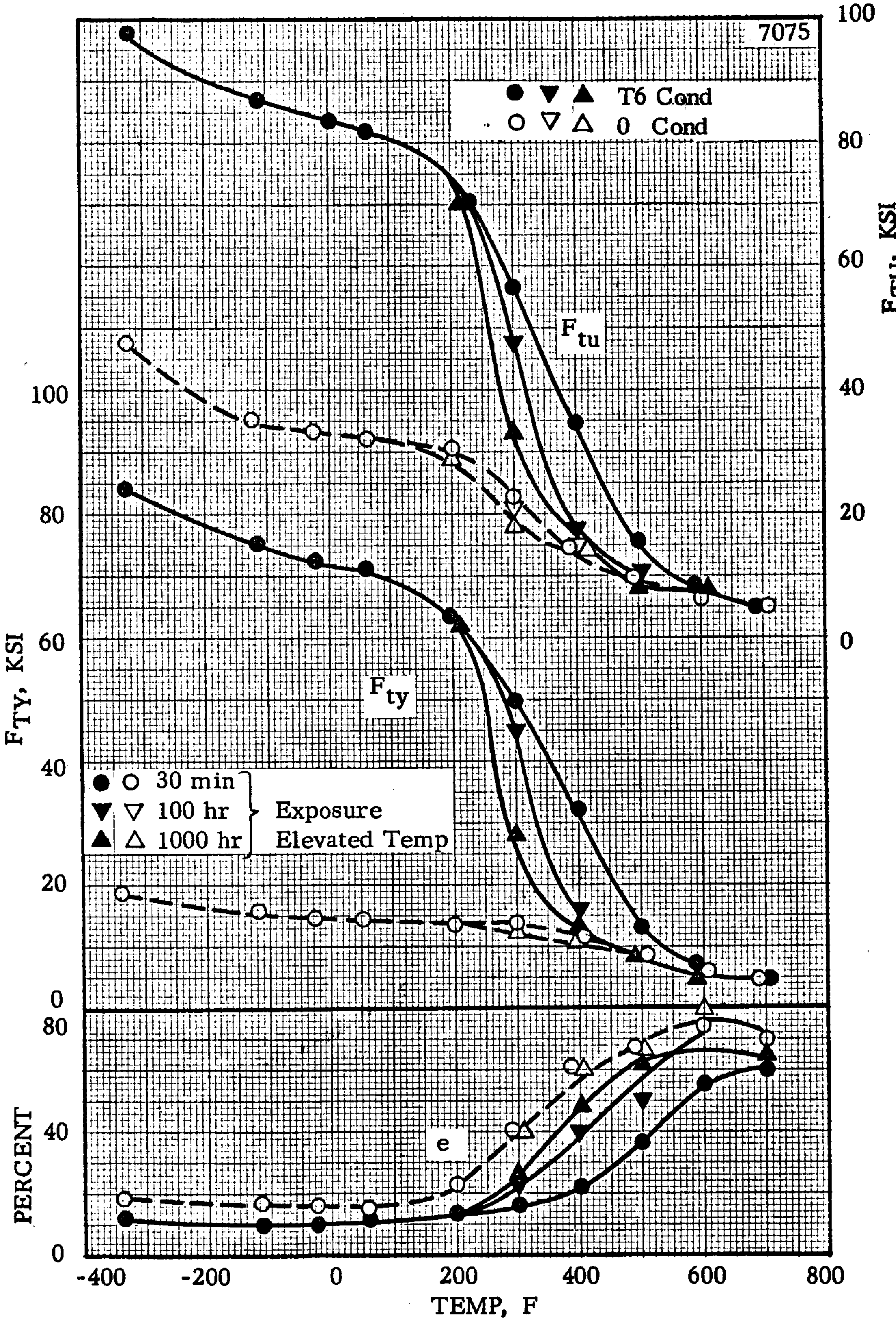

FIG. 7.4131 EFFECT OF EXPOSURE AND TEST TEMPERATURE ON TENSILE PROPERTIES OF ALLOY IN 0 AND T6 CONDITIONS

(Refs. 7.13 and 7.15)

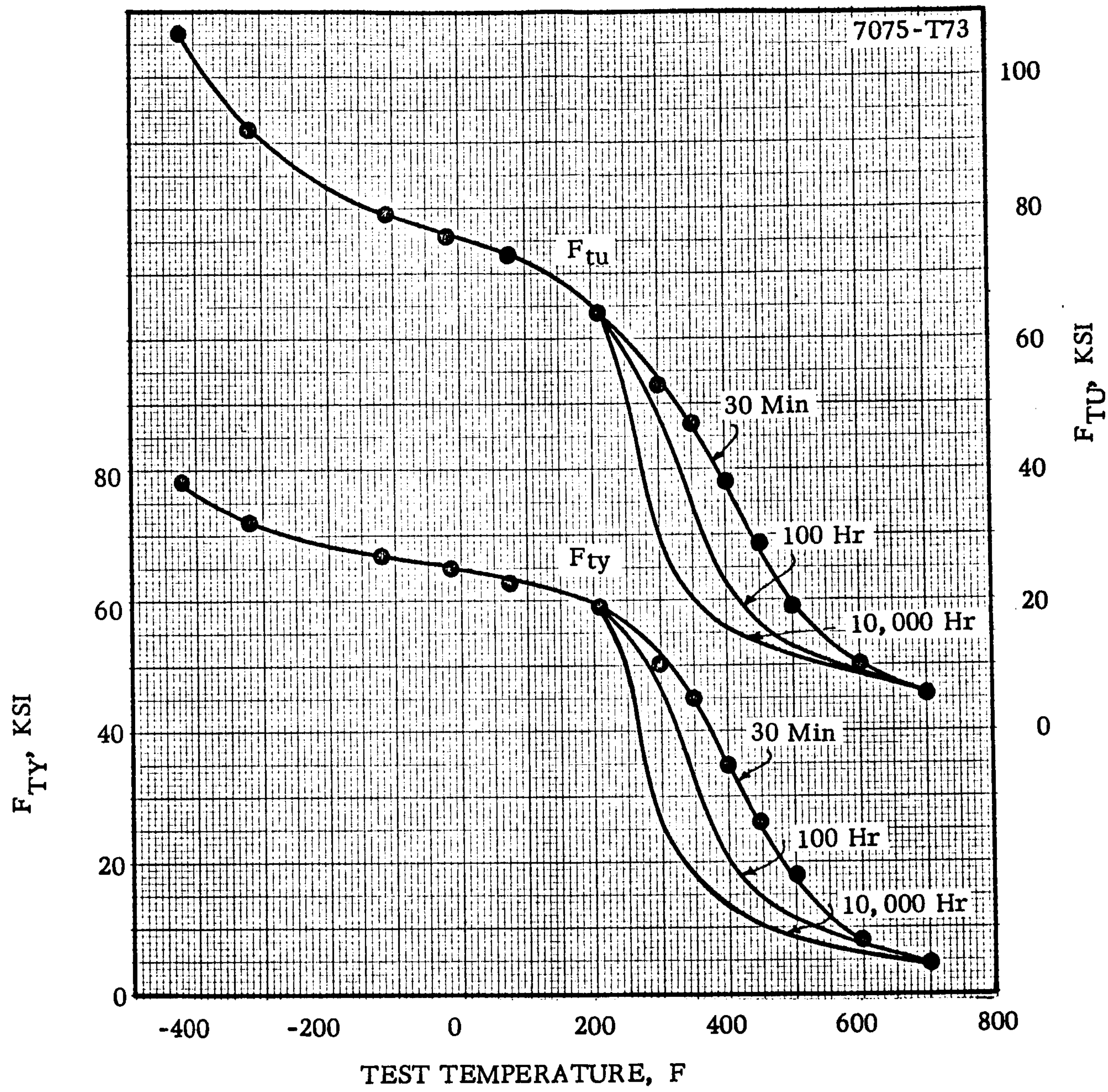

FIG. 7.4132 EFFECT OF TEST TEMPERATURE ON TENSILE PROPERTIES OF ALLOY IN T73 CONDITION (TYPICAL DATA)

(Ref. 7.16)

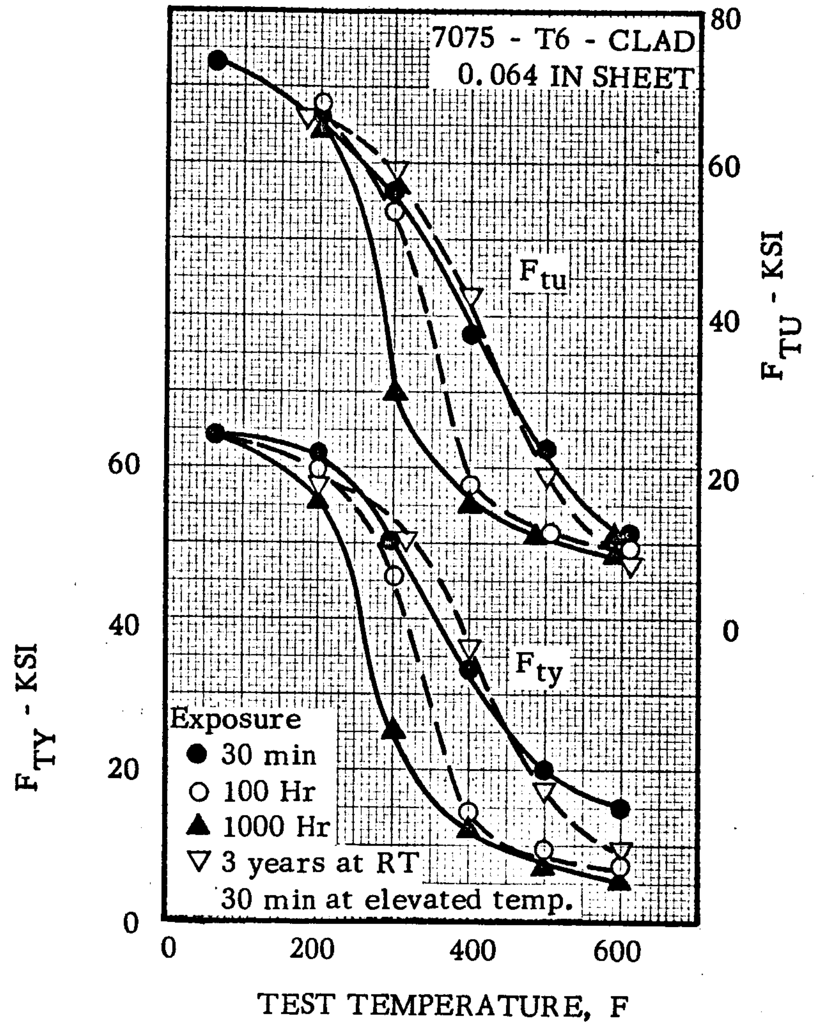

FIG. 7.4133 EFFECT OF EXPOSURE AND TEST TEMPERATURE ON TENSILE PROPERTIES OF SHEET IN T6 CONDITION

(Ref. 7.17)

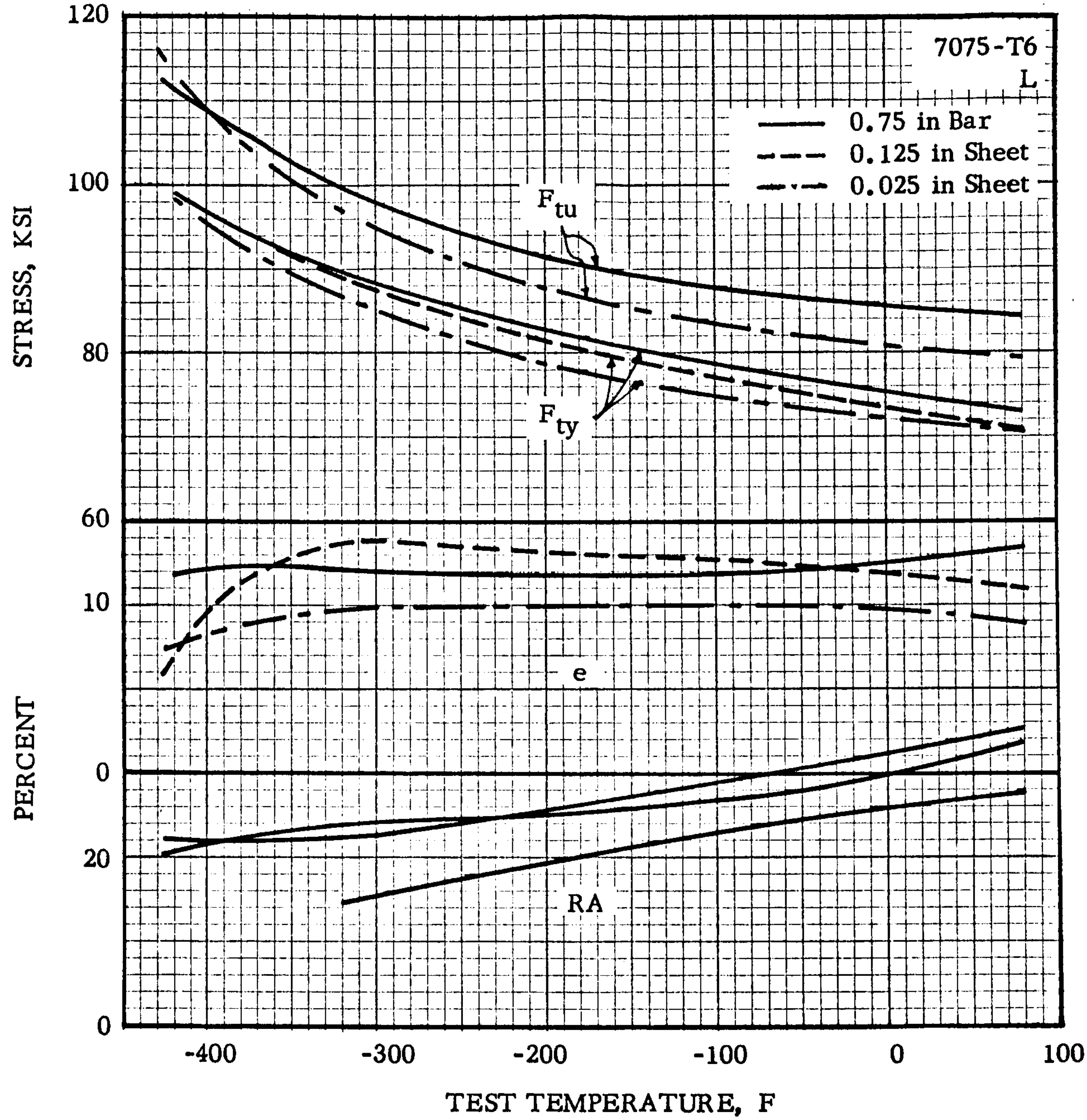

FIG. 7.4134 EFFECT OF LOW TEMPERATURES ON TENSILE PROPERTIES OF T6 SHEET AND BAR

(Ref. 7.11)

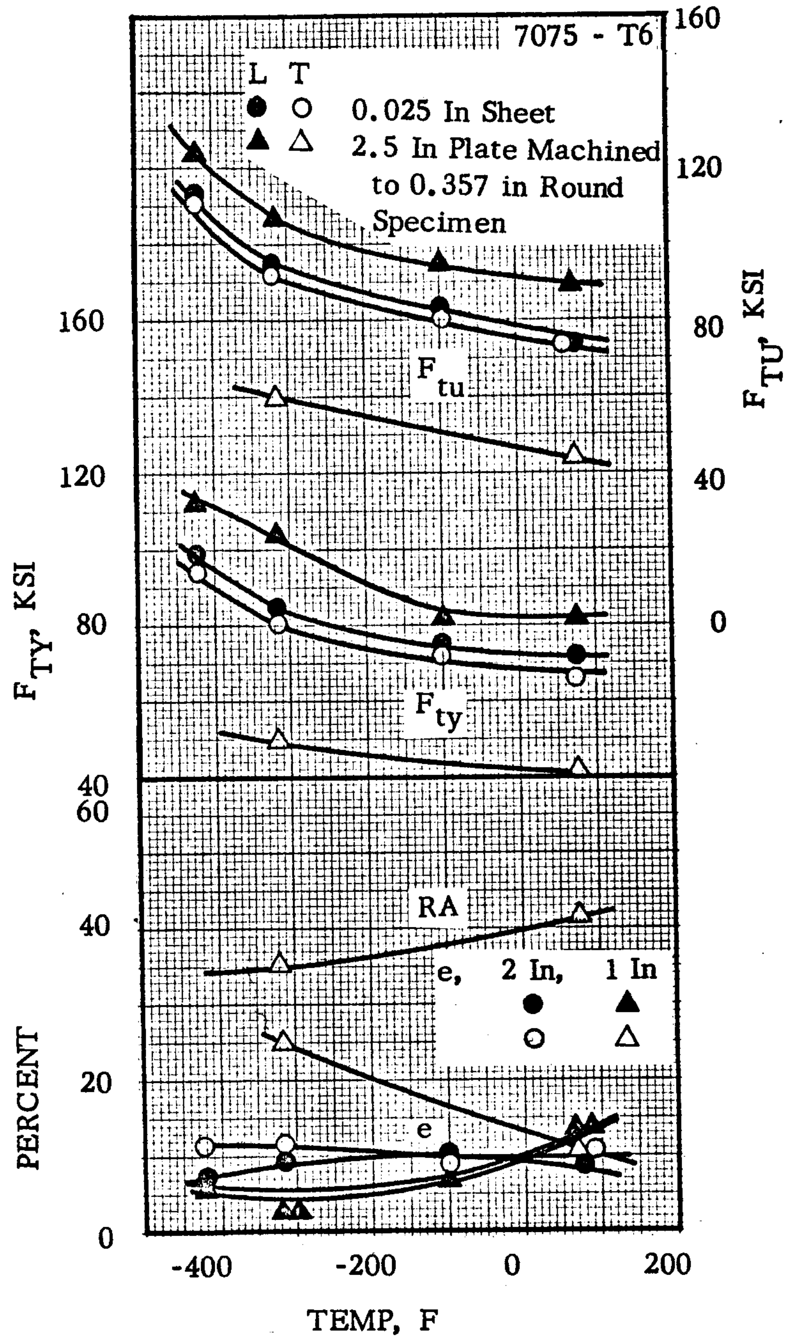

FIG. 7.4135 EFFECT OF LOW TEMPERATURES ON TENSILE PROPERTIES OF SHEET AND PLATE IN T6 CONDITION

(Ref. 7.18)

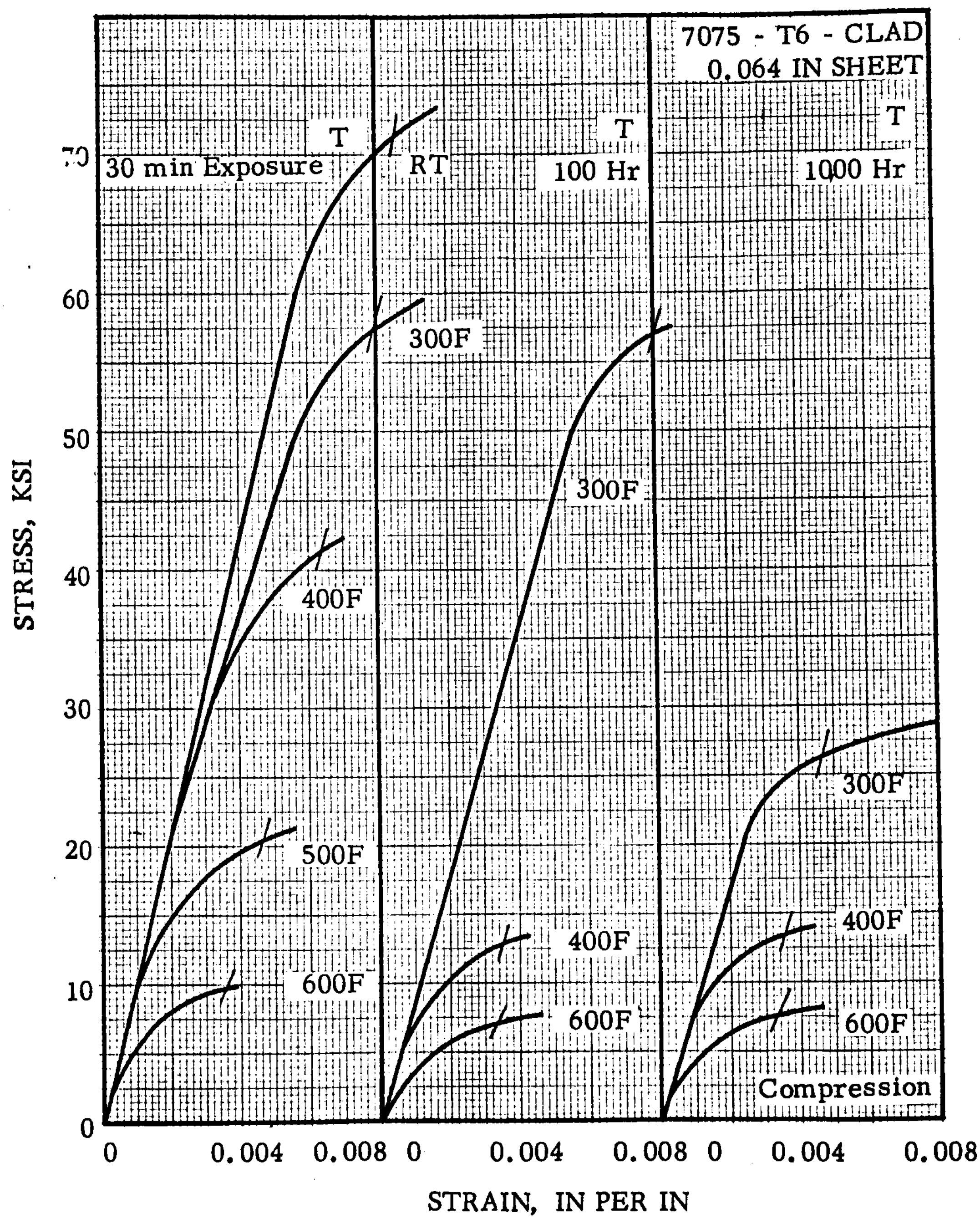

FIG. 7.4221 STRESS-STRAIN CURVES IN COMPRESSION FOR SHEET IN T6 CONDITION AT ROOM AND ELEVATED TEMPERATURES

(Ref. 7.10)

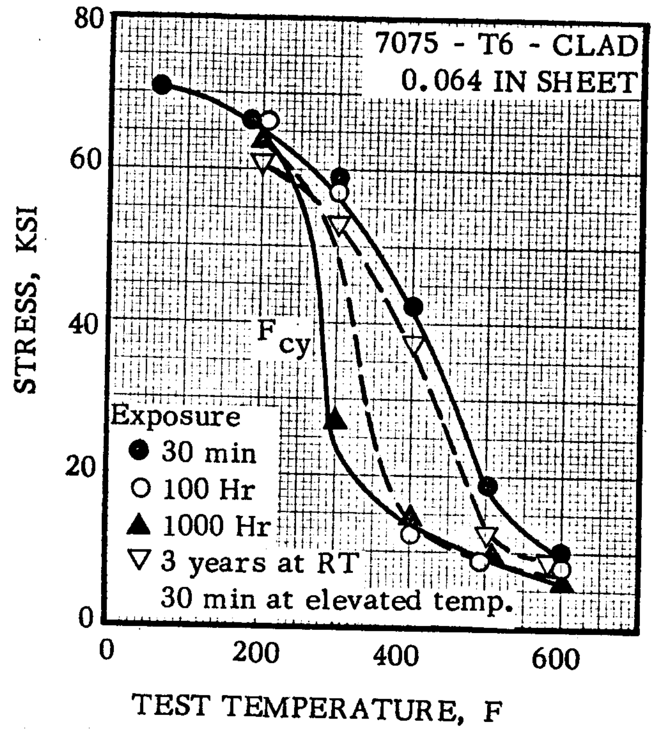

FIG. 7.4231 EFFECT OF EXPOSURE AND TEST TEMPERATURE ON COMPRESSIVE YIELD STRENGTH OF SHEET IN T6 CONDITION

(Ref. 7.10)

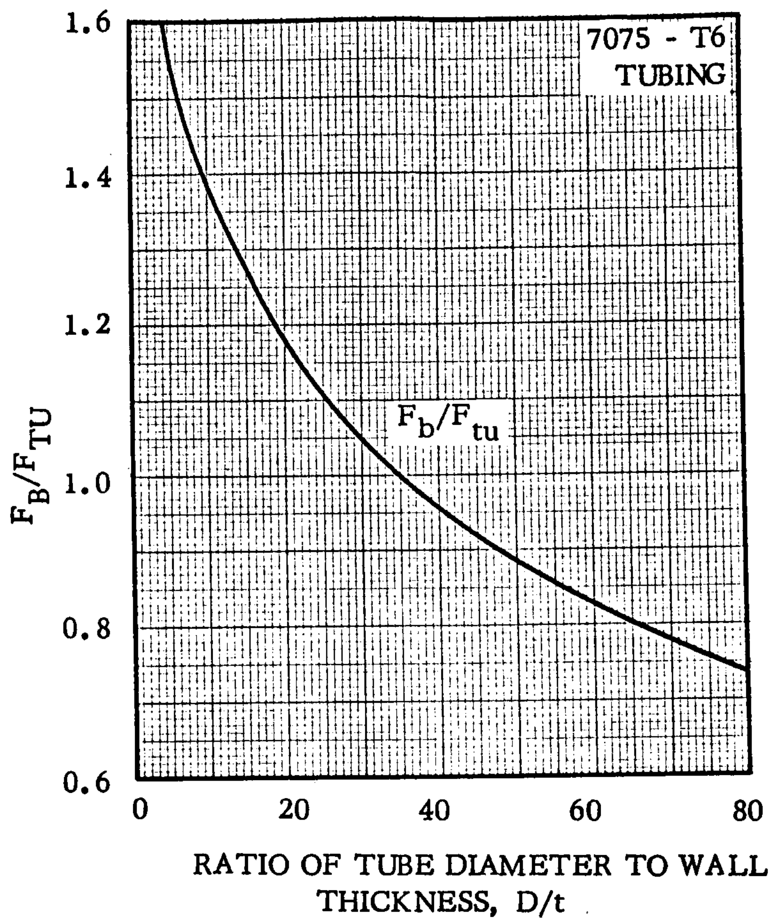

FIG. 7.431 RATIO OF BENDING MODULUS OF RUPTURE TO TENSILE STRENGTH FOR TUBING

(Ref. 7.5)

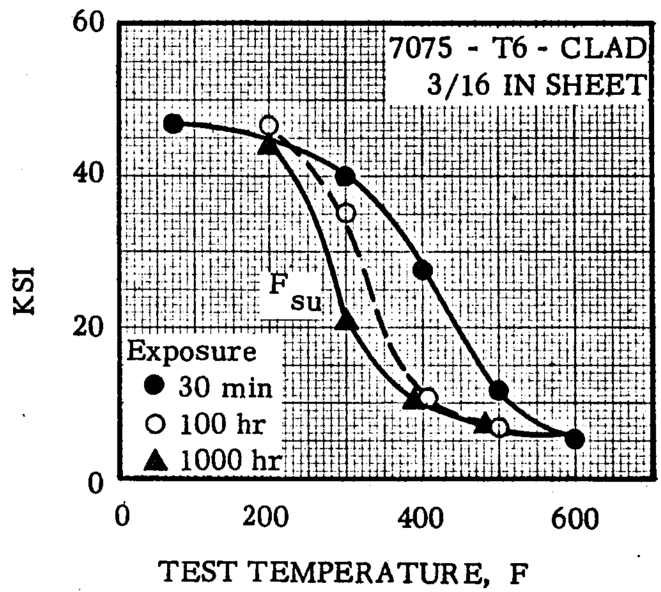

FIG. 7.4418 EFFECT OF EXPOSURE AND TEST TEMPERATURE ON SHEAR STRENGTH OF SHEET IN T6 CONDITION

(Refs. 7.10 and 7.19)

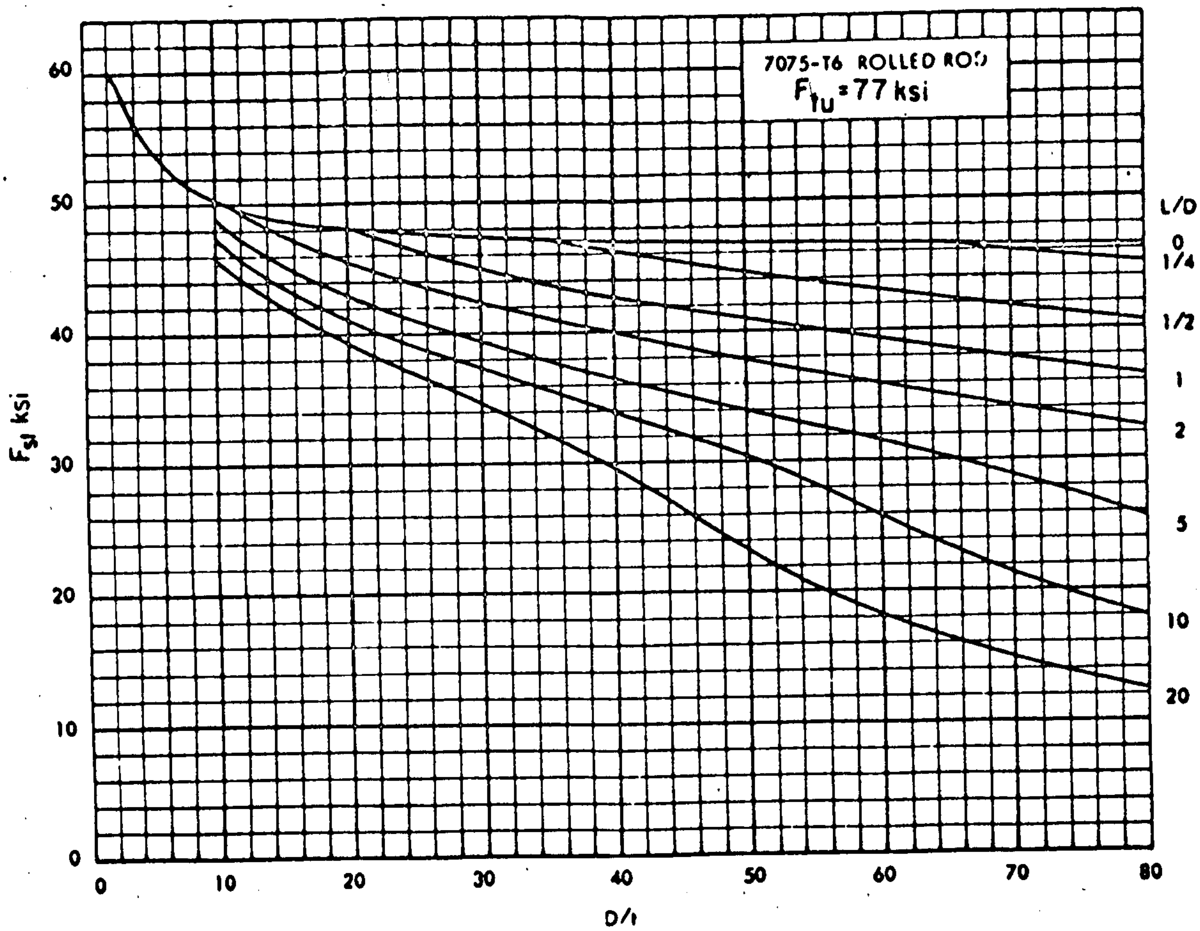

FIG. 7.4421 TORSIONAL MODULUS OF RUPTURE FOR T6 ROLLED ROD

(Ref. 7.5)

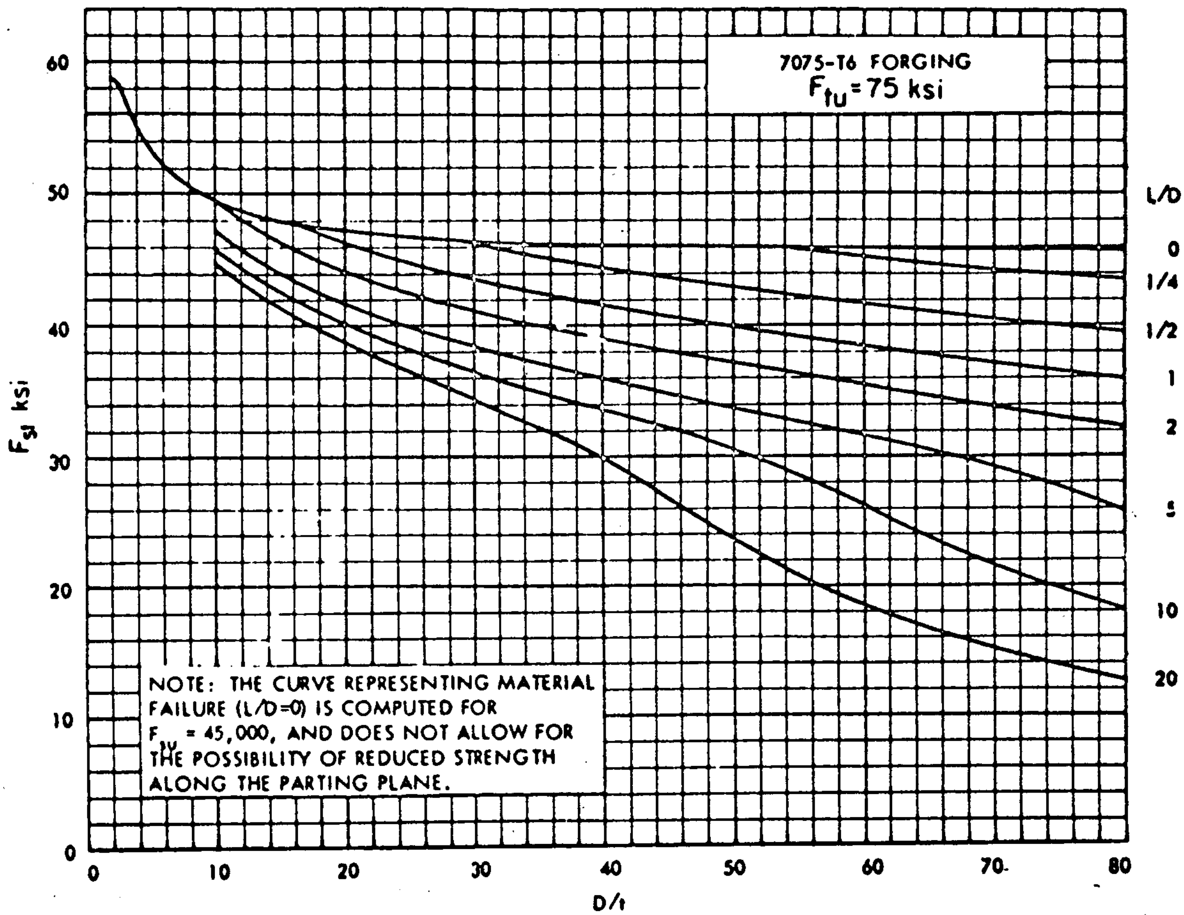

FIG. 7.4422 TORSIONAL MODULUS OF RUPTURE FOR T6 FORGINGS

(Ref. 7.5)

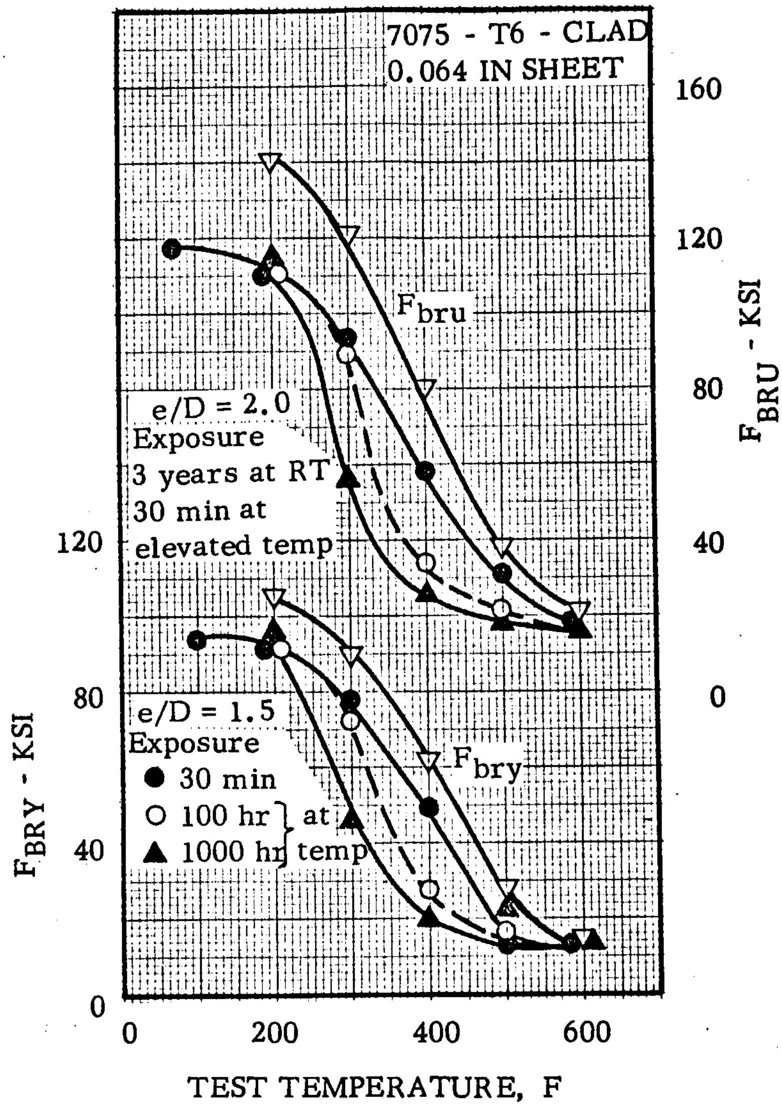

FIG. 7.4519 EFFECT OF EXPOSURE AND TEST TEMPERATURE ON BEARING PROPERTIES OF SHEET IN T6 CONDITION

(Refs. 7.10 and 7.19)

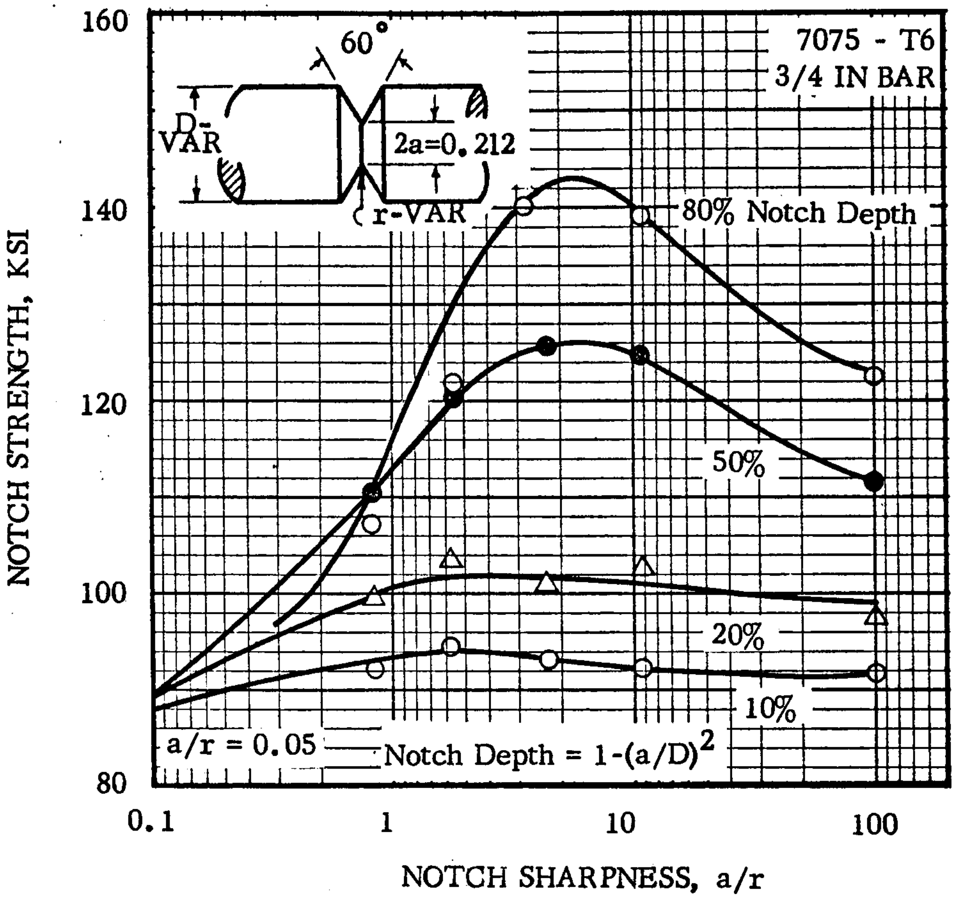

FIG. 7.4611 EFFECT OF NOTCH SHARPNESS AND NOTCH DEPTH ON NOTCH STRENGTH OF BAR IN T6 CONDITION

(Ref. 7.20)

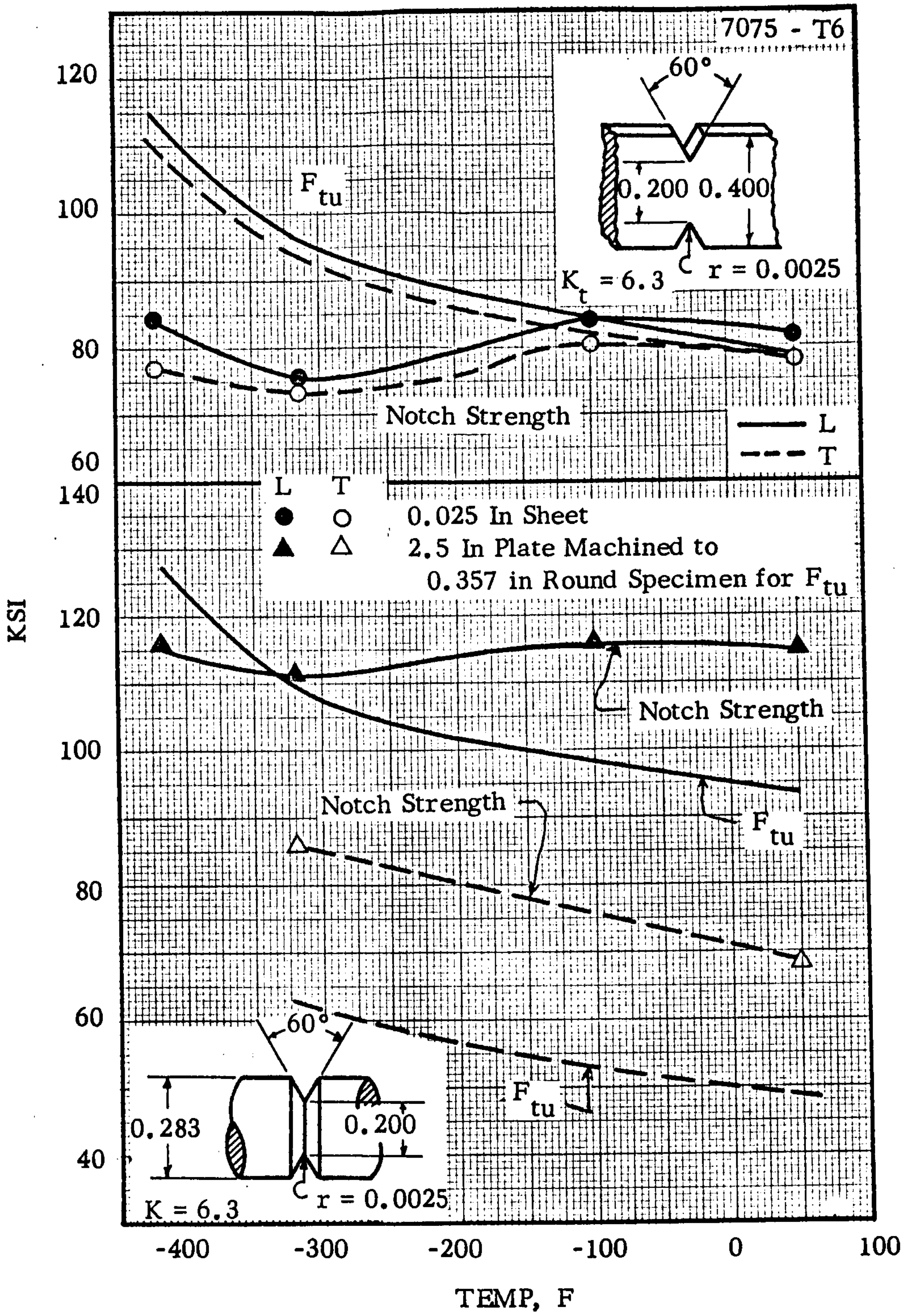

FIG. 7.4612 EFFECT OF LOW TEMPERATURES ON NOTCH STRENGTH OF SHEET AND PLATE IN T6 CONDITION

(Ref. 7.18)

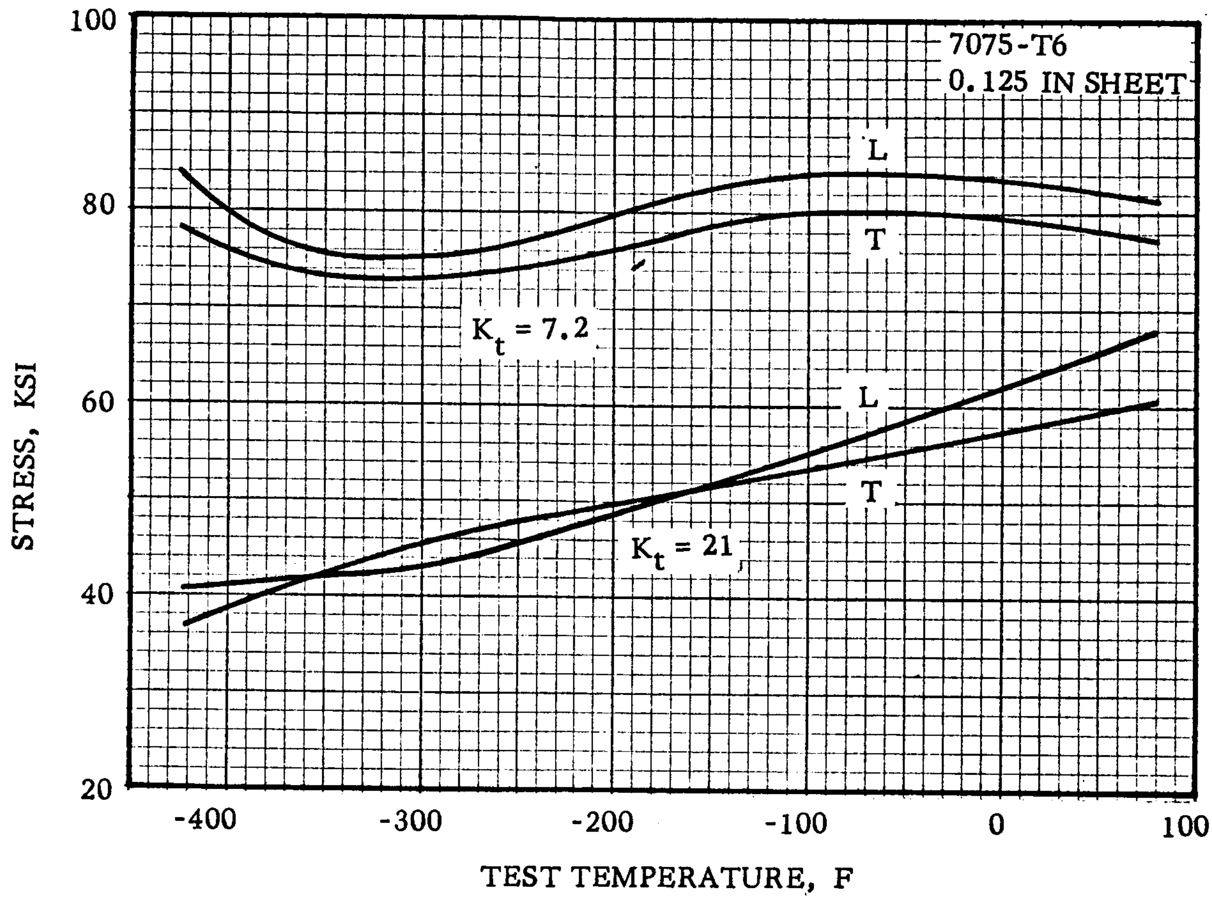

FIG. 7.4613 EFFECT OF LOW TEMPERATURES ON NOTCH STRENGTH OF T6 SHEET

(Ref. 7.11)

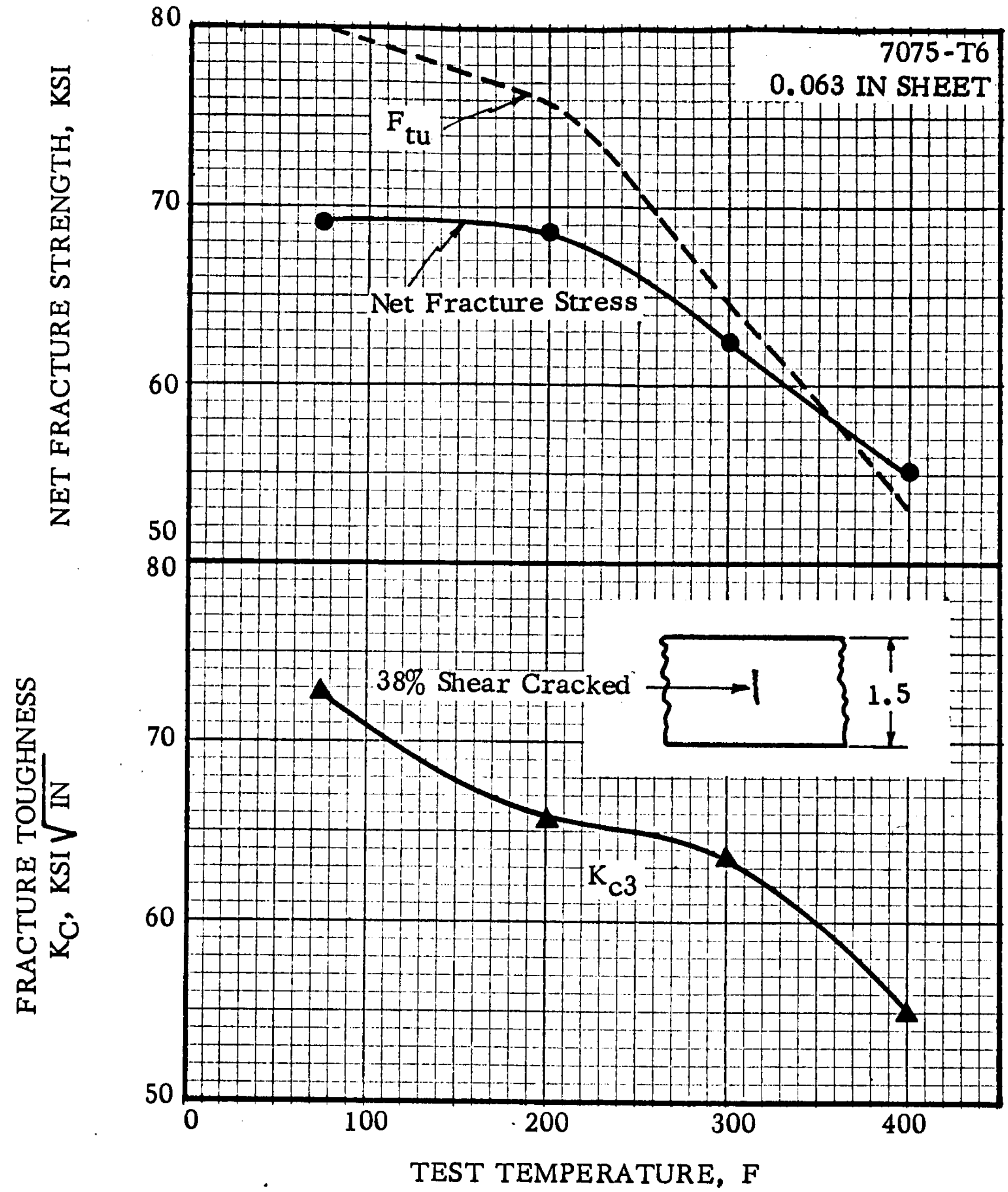

FIG. 7.4621 NET FRACTURE STRESS AND FRACTURE TOUGHNESS OF SHEET AT ELEVATED TEMPERATURES

(Ref. 7.21)

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CHAPTER 8

DYNAMIC AND TIME DEPENDENT PROPERTIES

8.1 General. The room temperature strength of the 7075 alloy is among the highest attainable with aluminum alloys. Its elevated temperature strength, however, is inferior to other aluminum-copper alloys such as 2014, 2024 and 2219.

8.2 Specified Properties

8.3 Impact

8.31 Low temperature impact strength of bar and rod in T6 Condition, Fig. 8.31.

8.32 Effect of test temperature on impact strength of alloy in T6 Condition, Fig. 8.32.

8.4 Creep

8.41 Creep-rupture

8.411 Creep and creep rupture curves for all products in T6 and T651 Conditions (except extrusions and forgings), Fig. 8.411.

8.412 Creep and creep rupture curves for T6 and T6511 extrusions, Fig. 8.412.

8.413 Creep and creep rupture curves for T73 products, Fig. 8.413.

8.42 Creep deformation

8.421 Short time total strain curves for Clad sheet in T6 Condition at 300 to 600F, Fig. 8.421.

8.422 Isochronous stress-strain curves at 300 and 400F for alloy in T6 Condition, Fig. 8.422.

8.423 Master parameter curves for 0.5 percent total strain and creep rupture for Clad sheet in T6 Condition, Fig. 8.423.

8.5 Stability

8.51 Exposure effects

8.511 Effect of exposure to elevated temperatures on room temperature tensile properties of alloy in T6 Condition, Fig. 8.511.

8.6 Fatigue

8.61 Controlled stress cycling

8.611 Mean fatigue strength of smooth and notch bar and sheet, Fig. 8.611.

8.612 Typical constant-life diagram for various wrought products, Fig. 8.612.

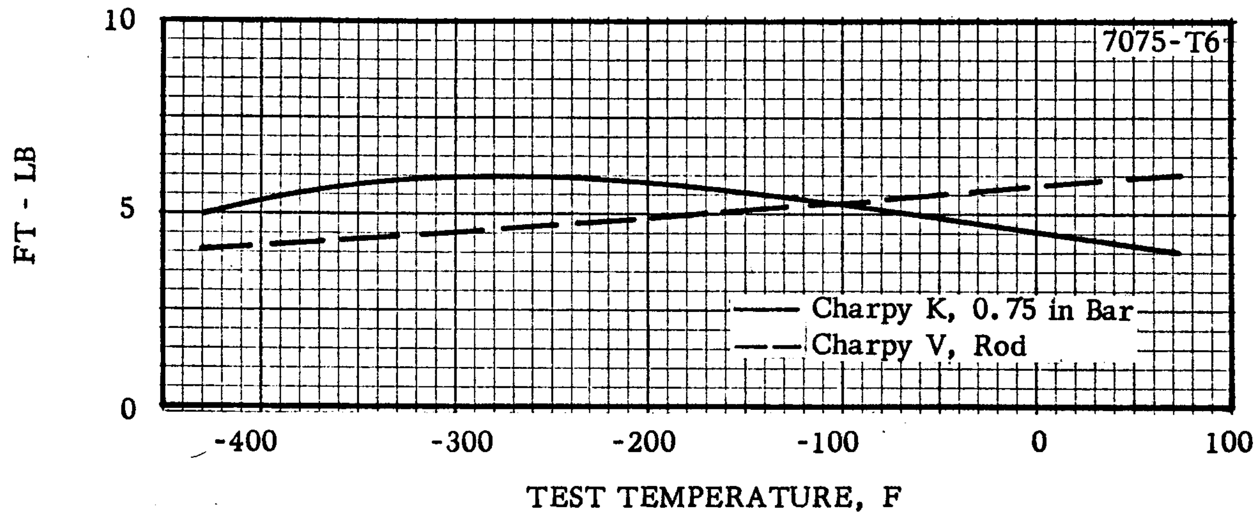

FIG. 8.31 LOW TEMPERATURE IMPACT STRENGTH OF BAR AND ROD IN T6 CONDITION

(Ref. 8.1)

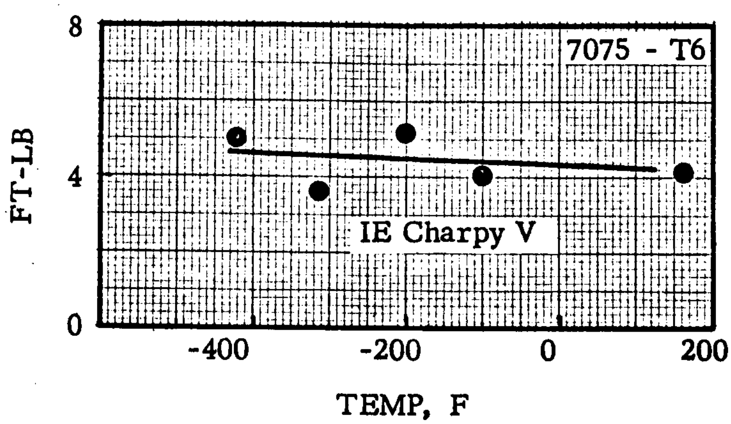

FIG. 8.32 EFFECT OF TEST TEMPERATURE ON IMPACT STRENGTH OF ALLOY IN T6 CONDITION (Ref. 8.2)

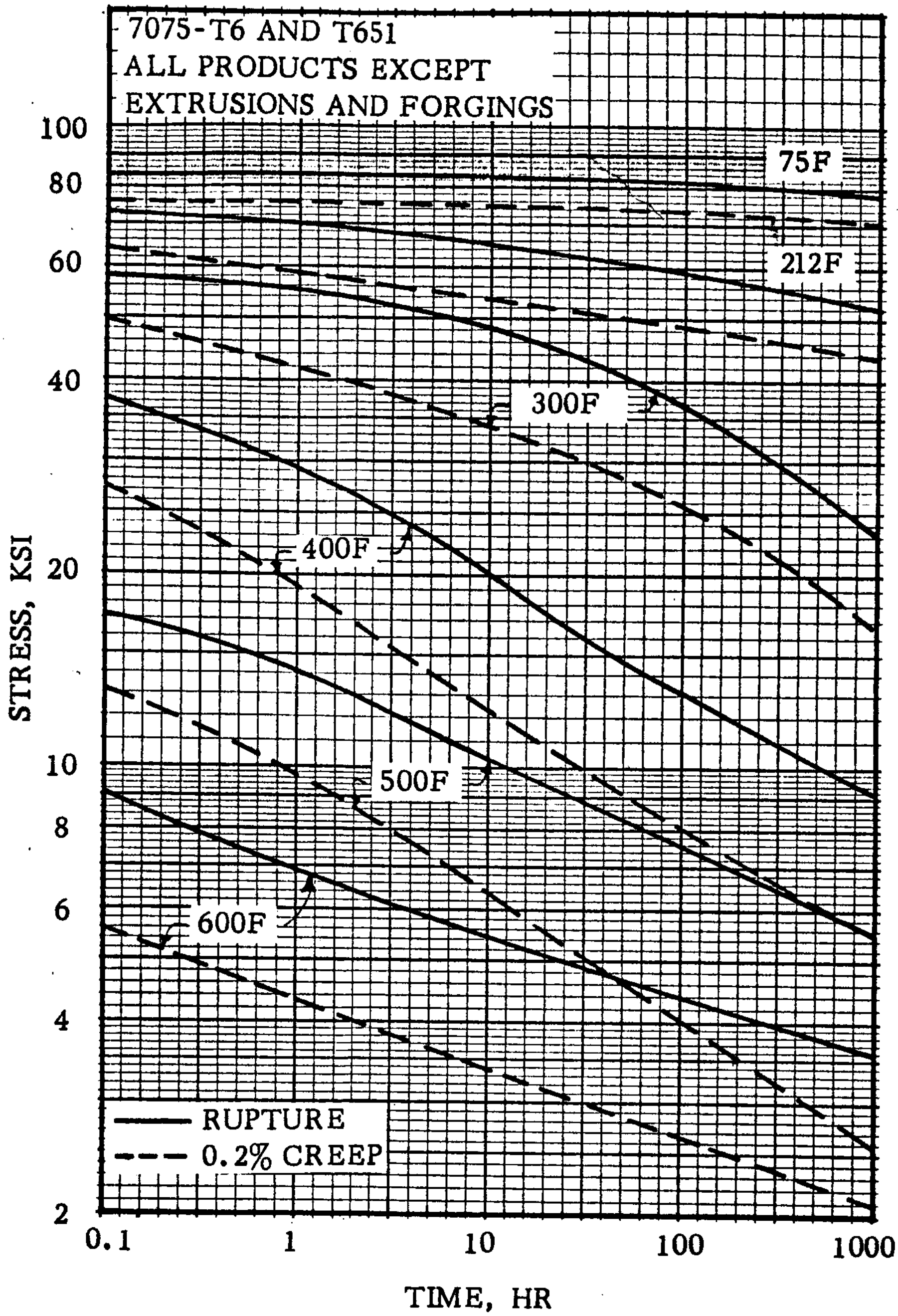

FIG. 8.411 CREEP AND CREEP RUPTURE CURVES FOR ALL PRODUCTS IN T6 AND T651 CONDITION(EXCEPT EXTRUSIONS AND FORGINGS)

(Ref.8.13)

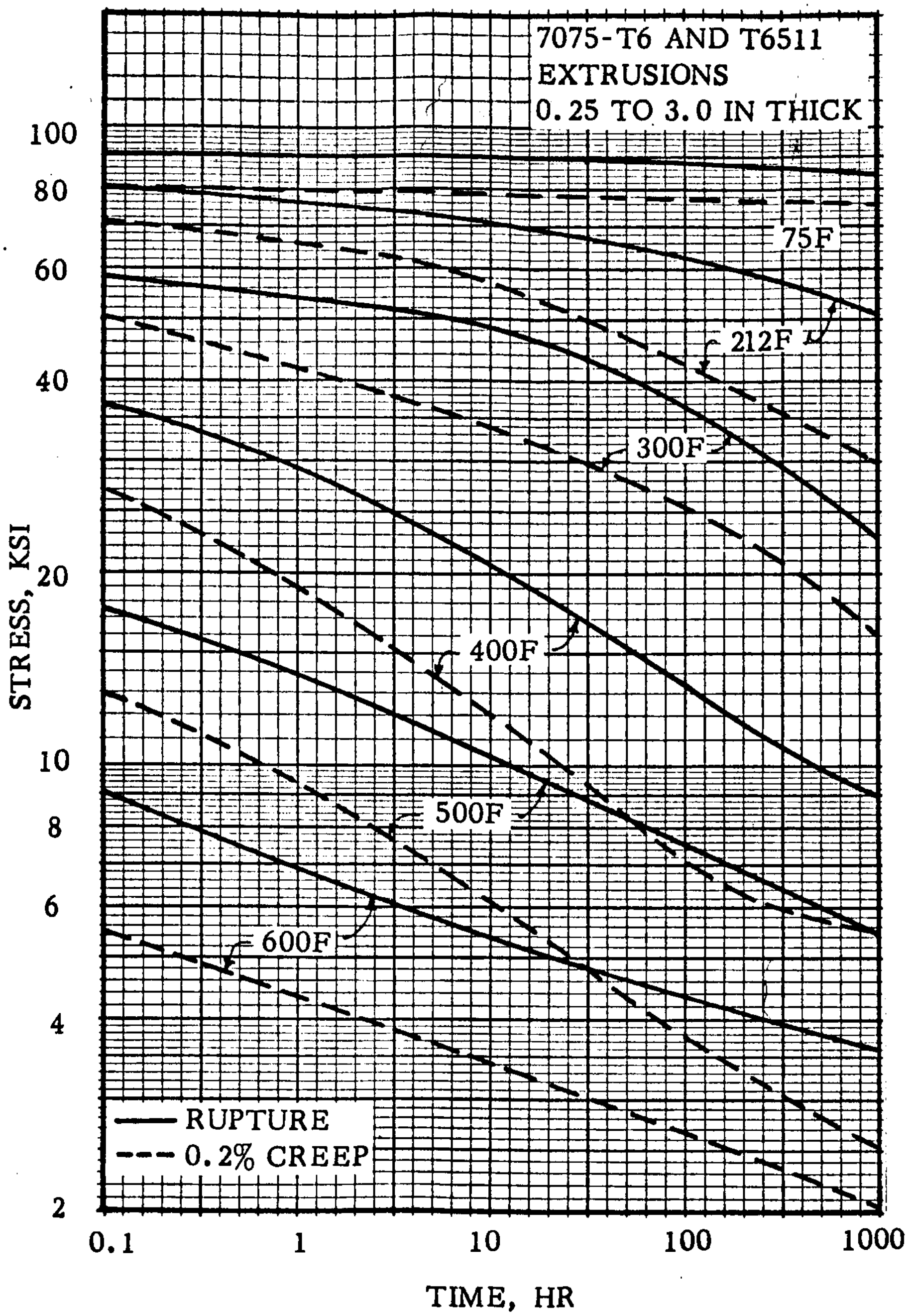

FIG. 8.412 CREEP AND CREEP RUPTURE CURVES FOR T6 AND T6511 EXTRUSIONS

(Ref. 8.13)

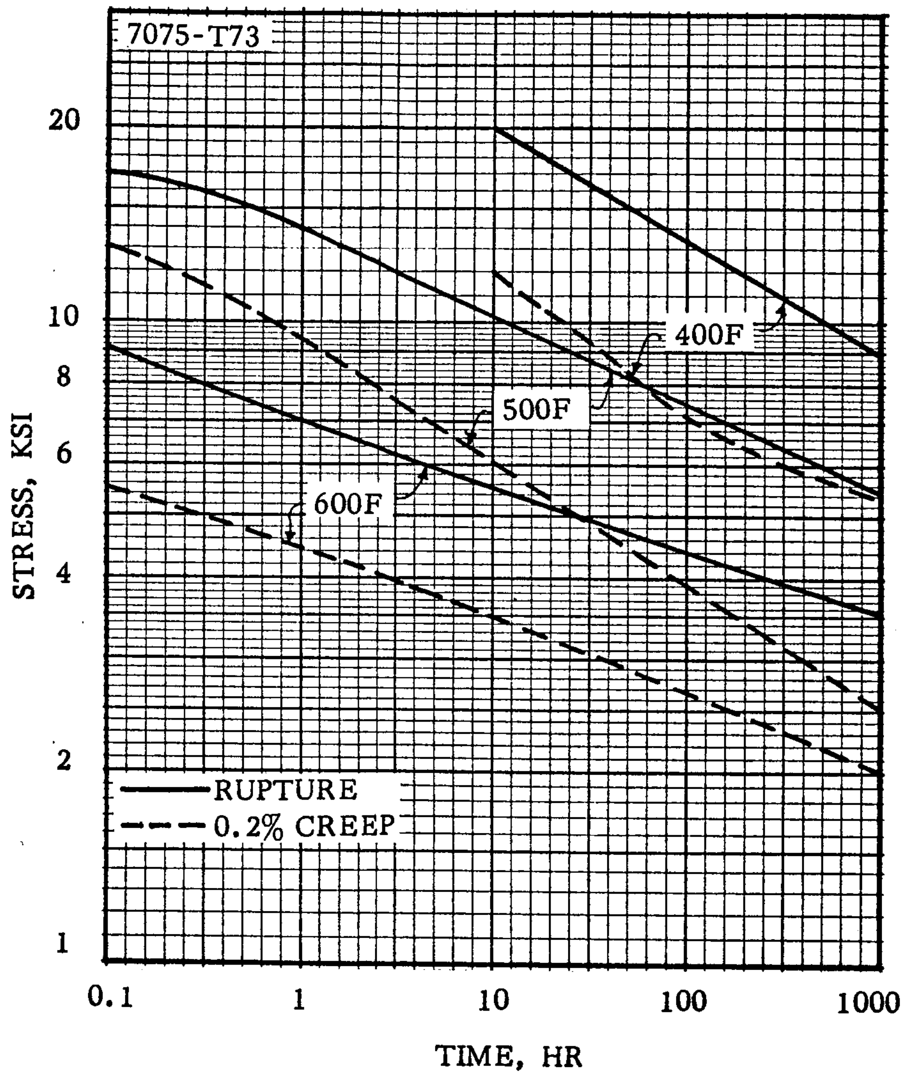

FIG. 8.413 CREEP AND CREEP RUPTURE CURVES FOR T73 PRODUCTS

(Ref. 8.13)

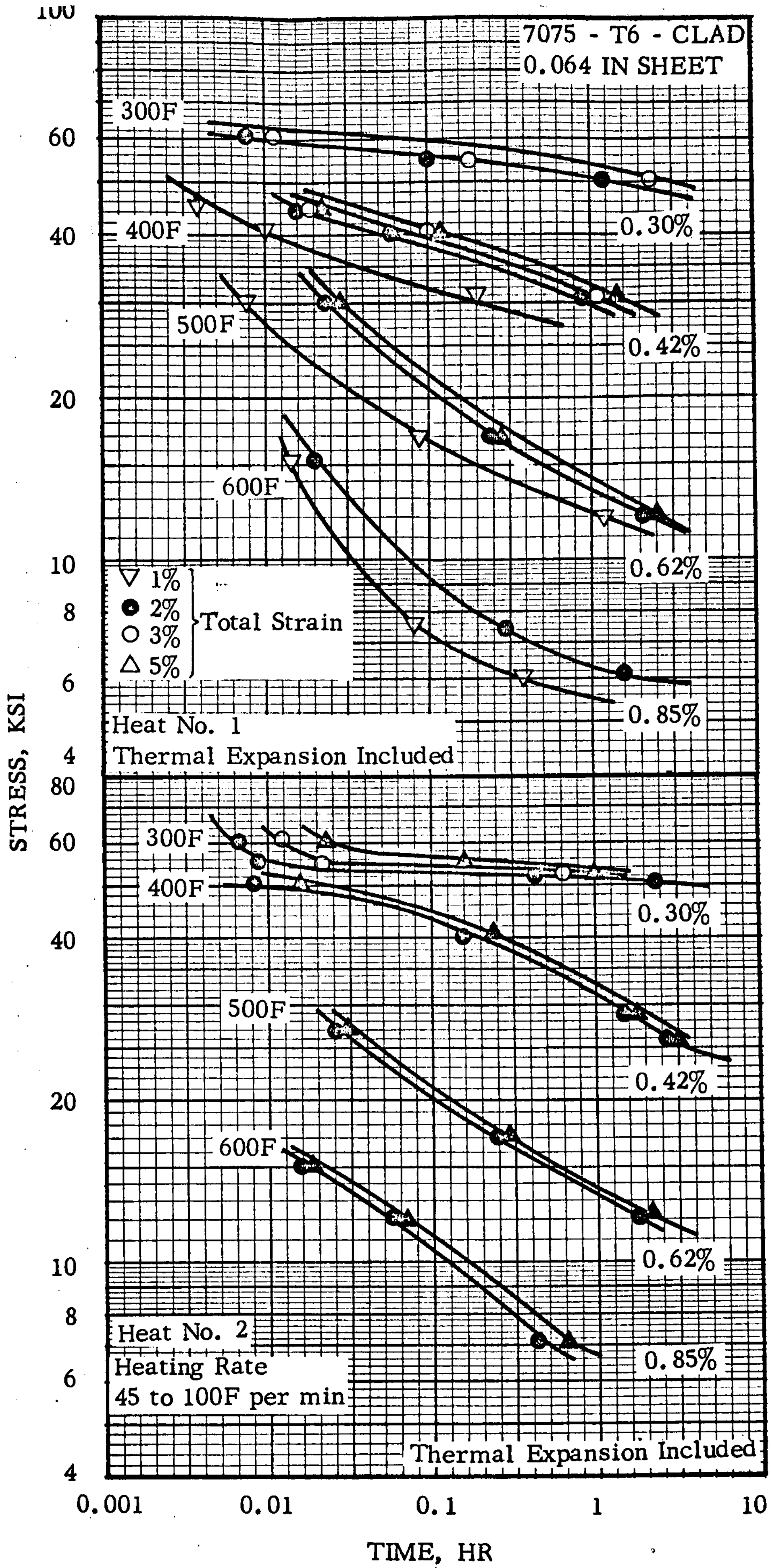

FIG. 8.421 SHORT TIME TOTAL STRAIN CURVES FOR SHEET IN T6 CONDITION AT 300 TO 600F

(Ref. 8.5)

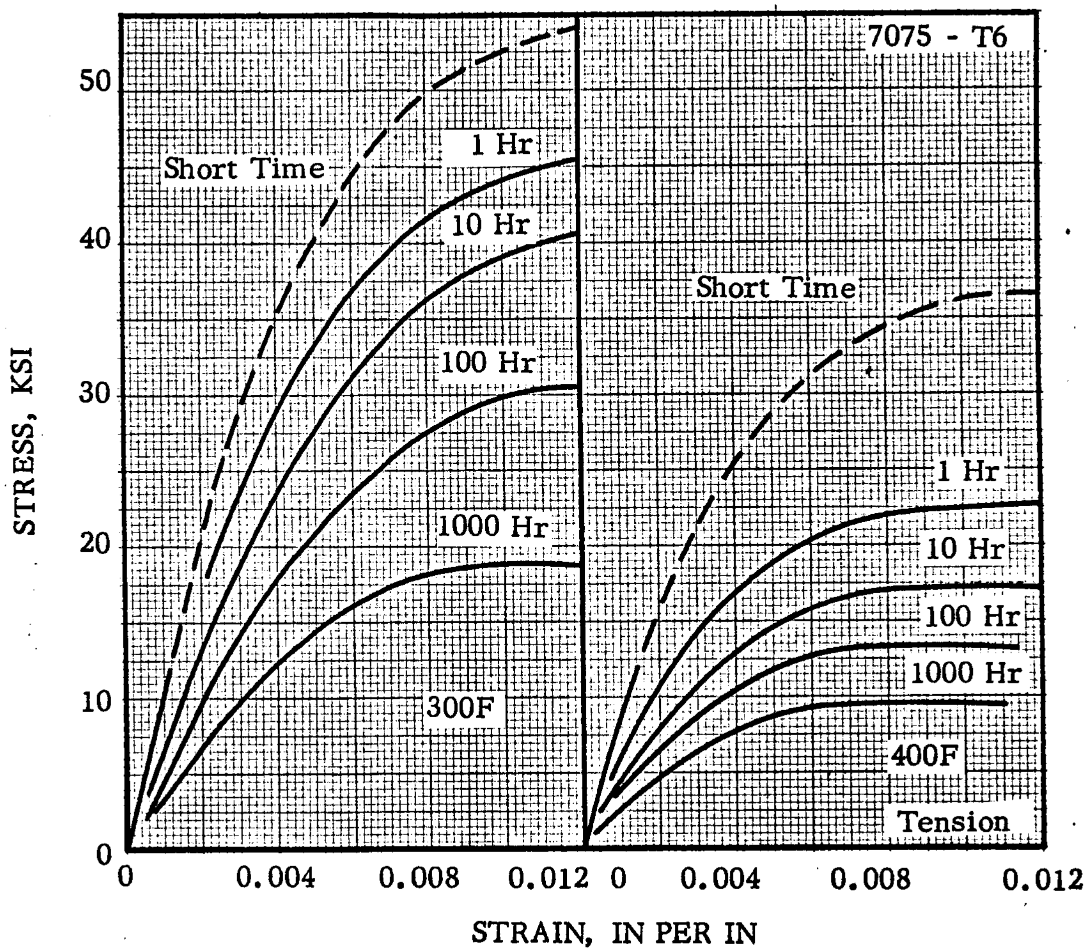

FIG. 8.422 ISOCHRONOUS STRESS-STRAIN CURVES AT 300 AND 400F FOR ALLOY IN T6 CONDITION

(Ref. 8.6)

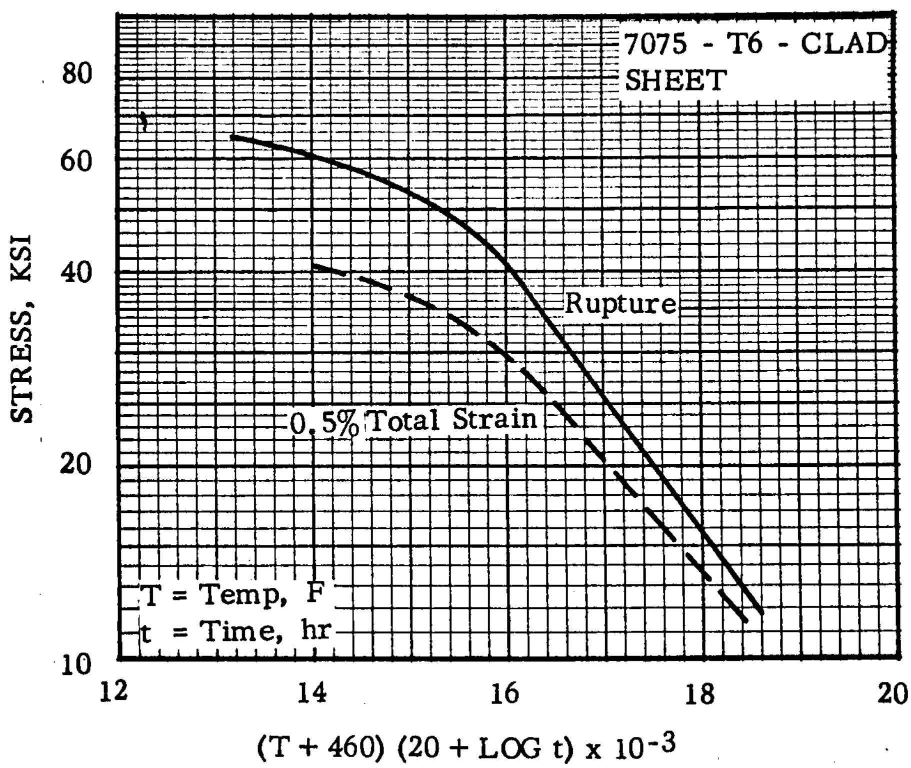

FIG. 8.423 MASTER CURVES FOR 0.5 PERCENT TOTAL STRAIN AND CREEP RUPTURE FOR SHEET IN T6 CONDITION

(Ref. 8.4)

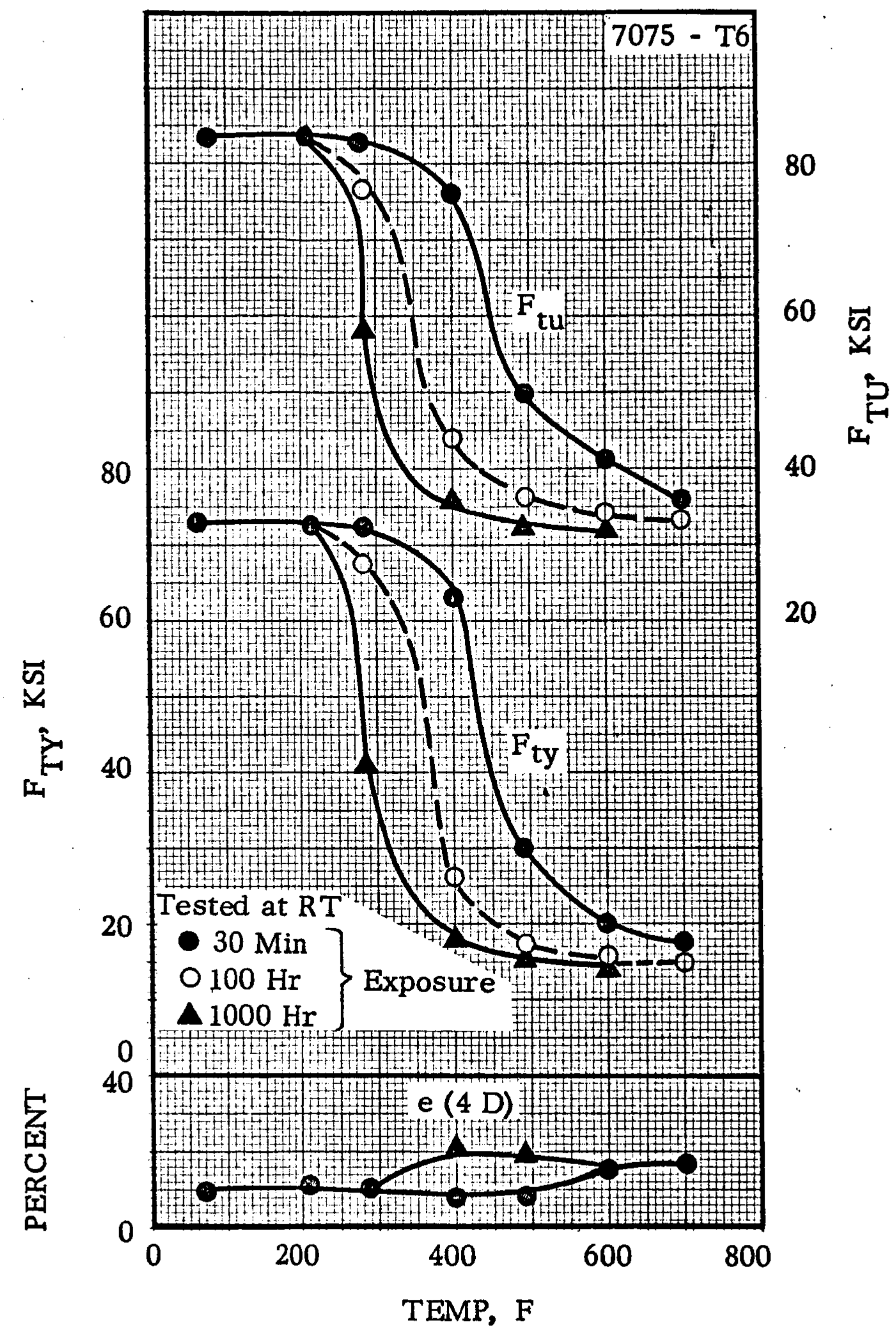

FIG. 8.511 EFFECT OF EXPOSURE TO ELEVATED TEMPERATURES ON ROOM TEMPERATURE TENSILE PROPERTIES OF ALLOY IN T6 CONDITION

(Ref. 8.3)

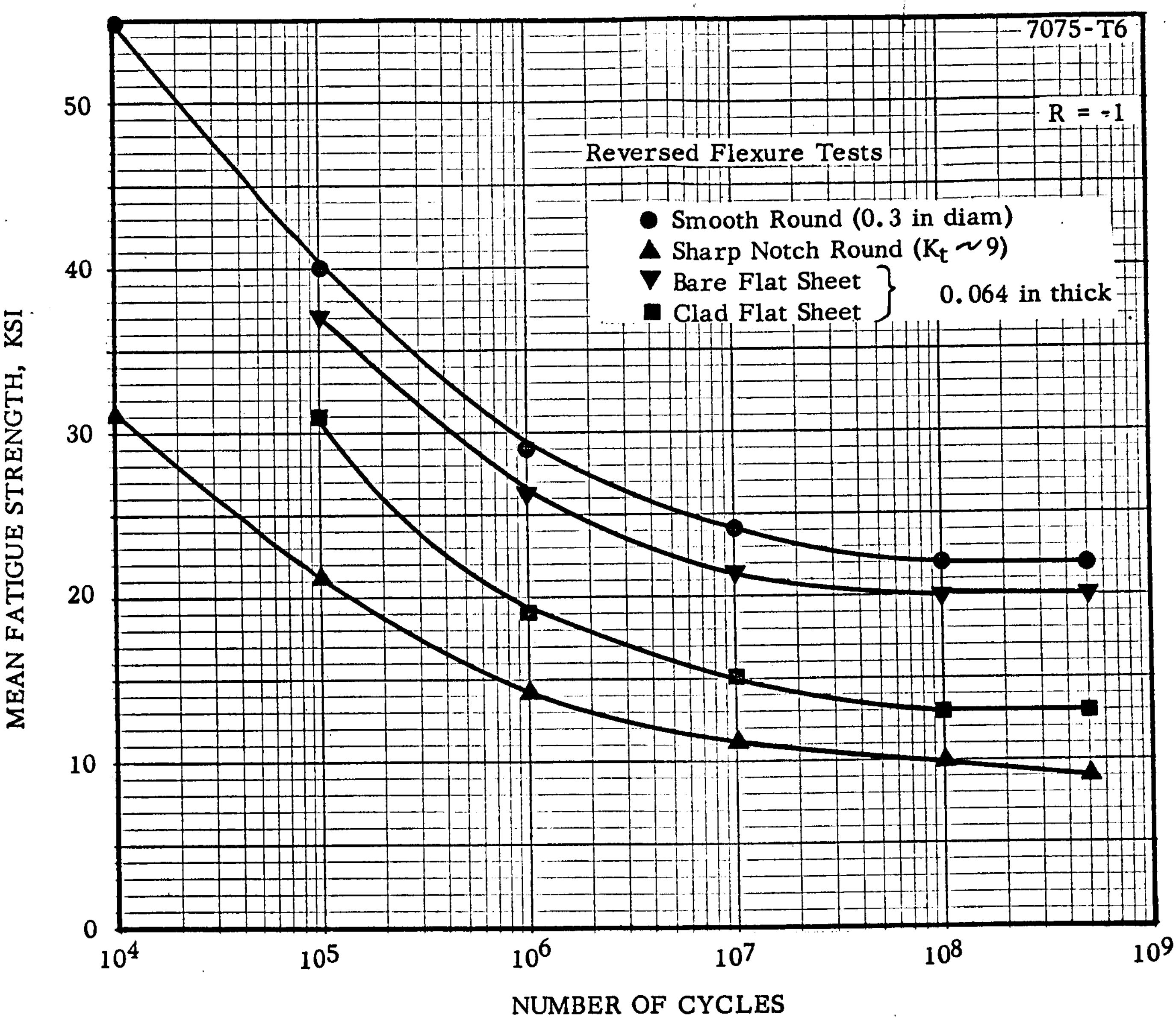

FIG. 8.611 MEAN FATIGUE STRENGTH OF SMOOTH AND NOTCHED BAR AND SHEET (Ref. 8.7)

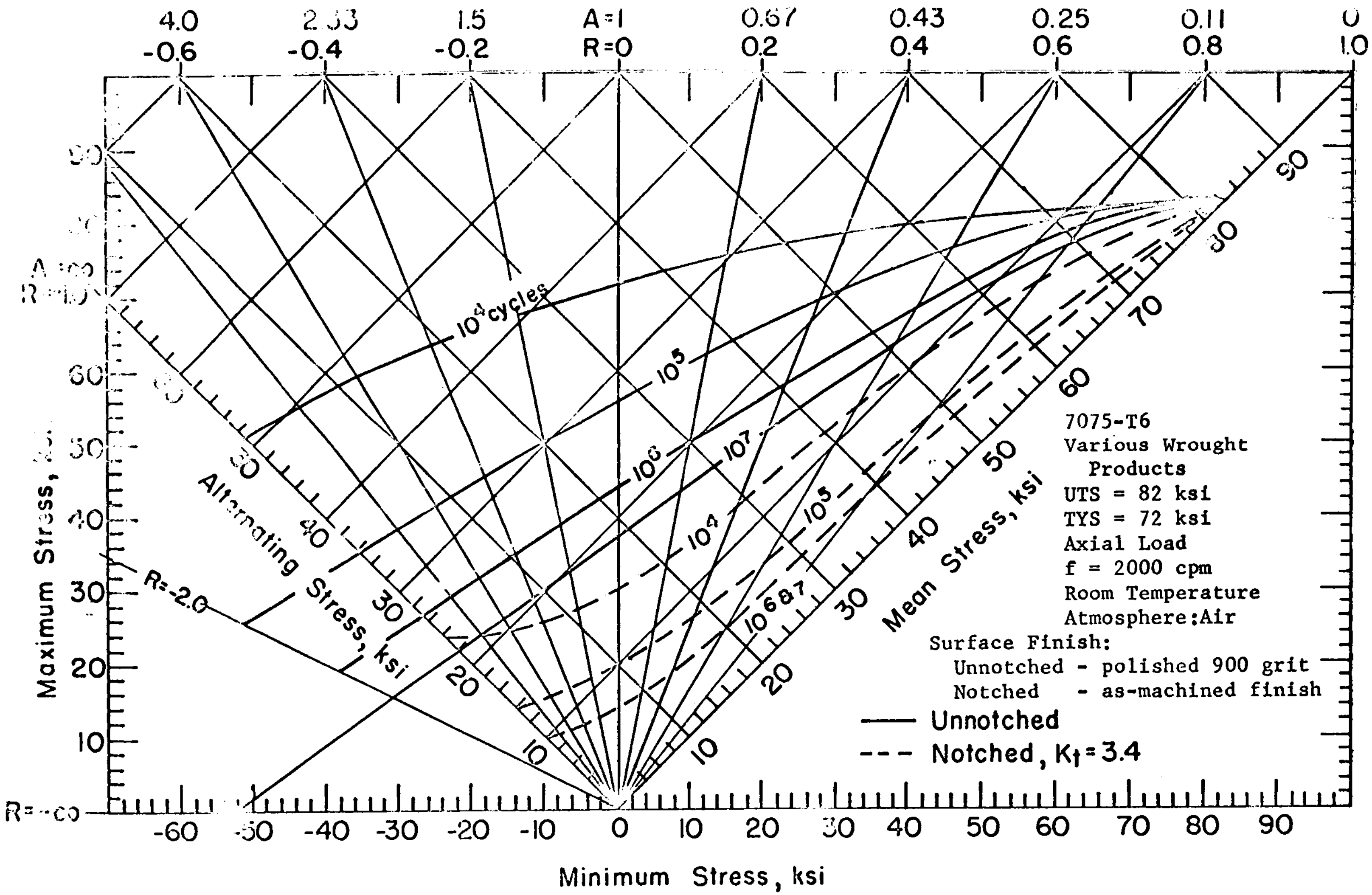

FIG. 8.612 TYPICAL CONSTANT-LIFE DIAGRAM FOR VARIOUS WROUGHT PRODUCTS

(Ref. 8.7)

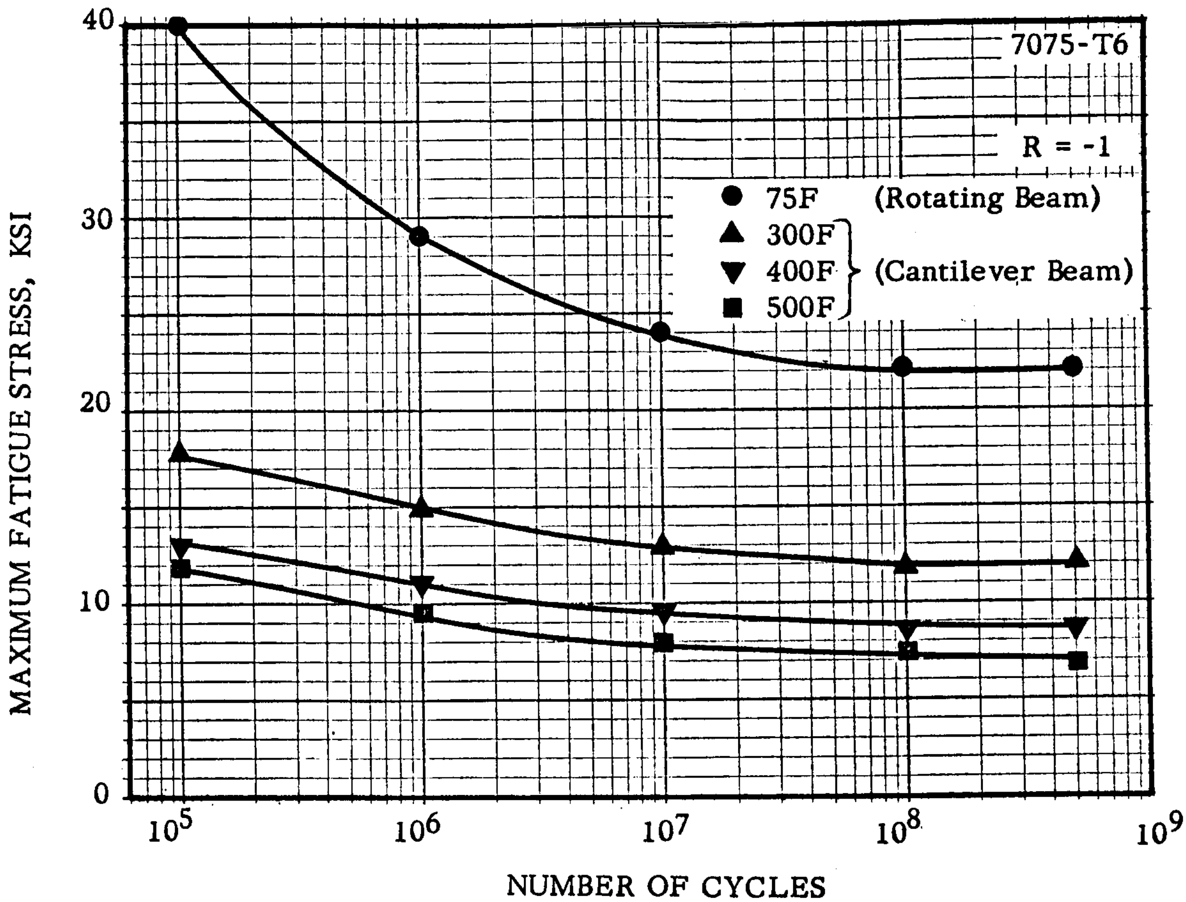

FIG. 8.613 CANTILEVER-BEAM FATIGUE STRENGTH AT ELEVATED TEMPERATURES (Ref. 8.7)

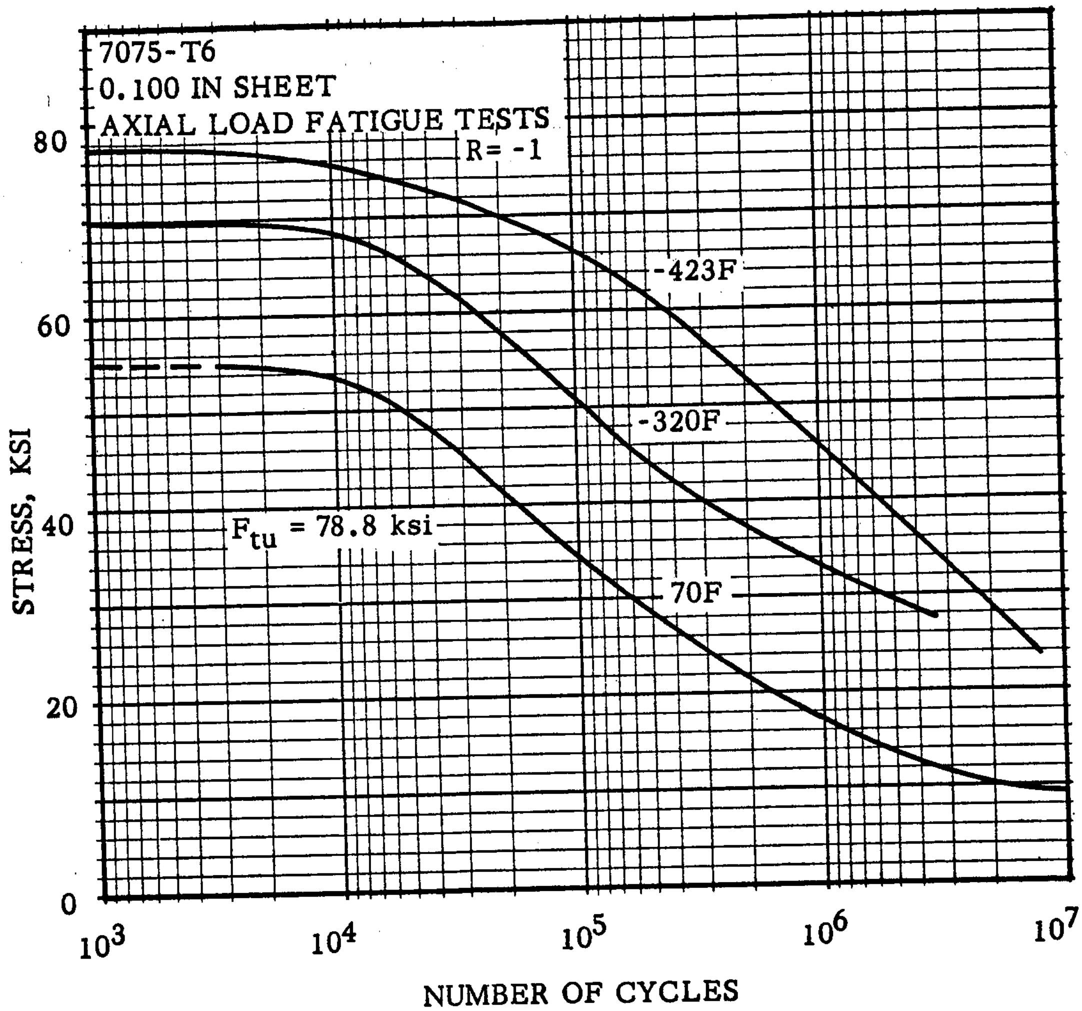

FIG. 8.614 S-N CURVES AT LOW TEMPERATURES FOR SHEET IN T6 CONDITION

(Ref. 8.1)

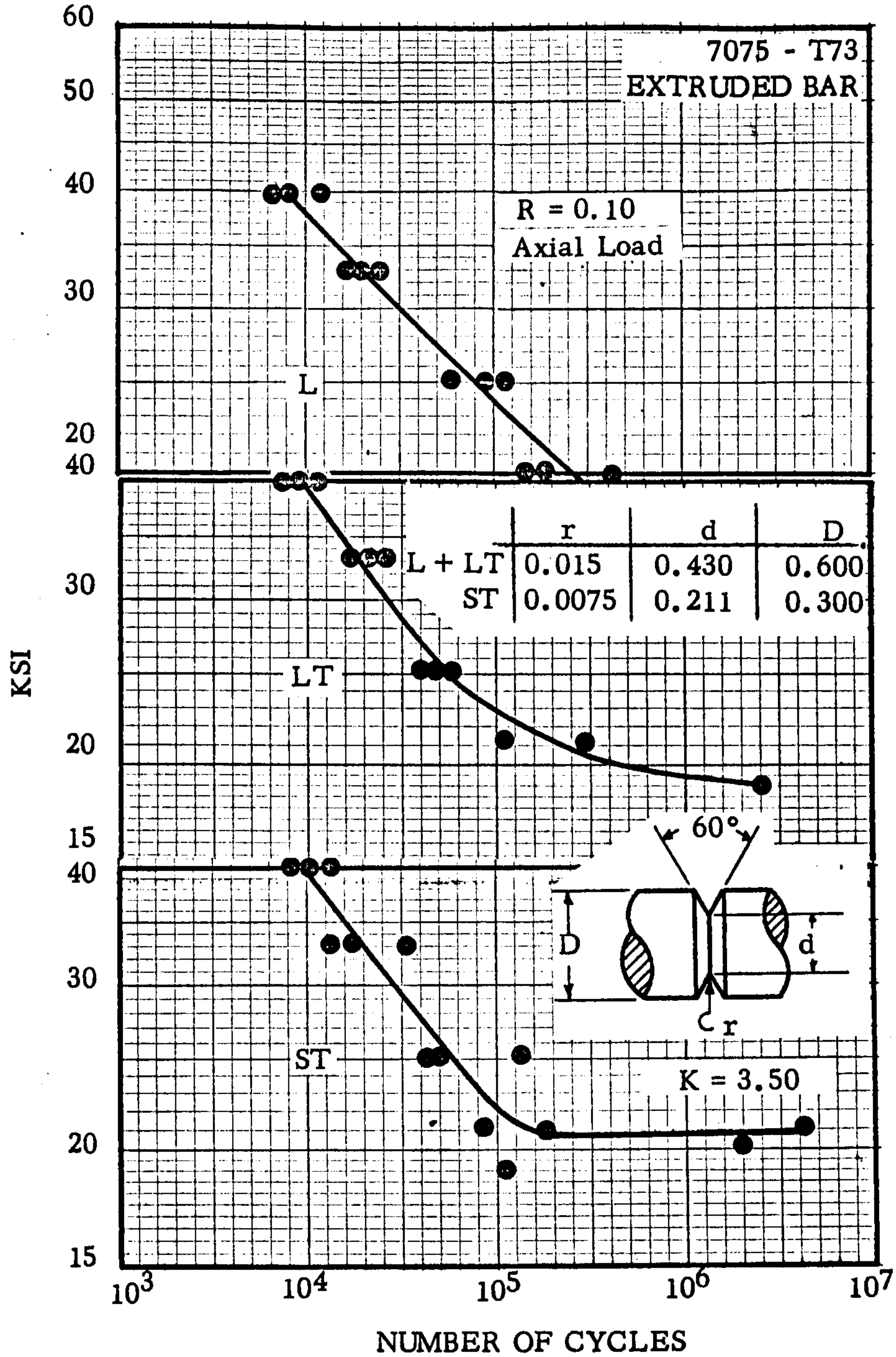

FIG. 8.615 S-N CURVES FOR EXTRUDED BAR IN T73 CONDITION

(Ref. 8.9)

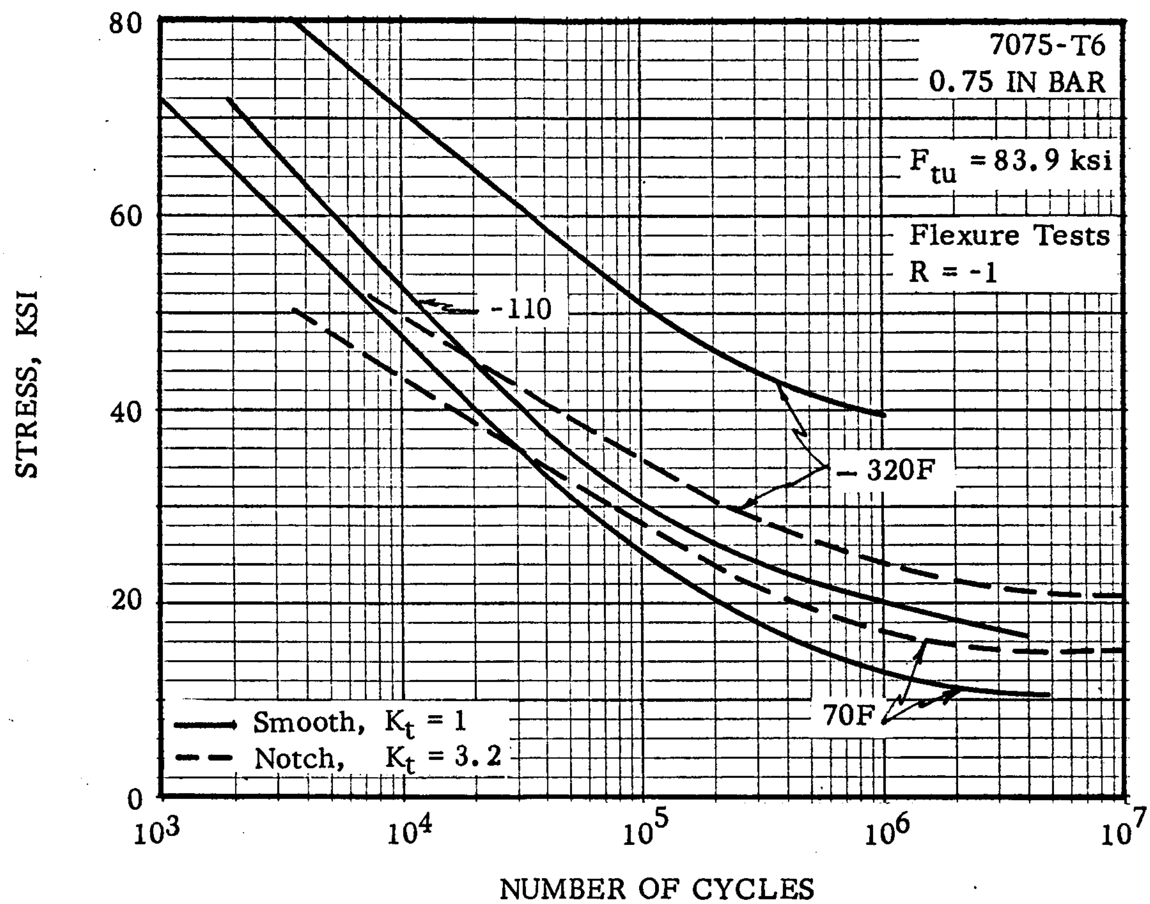

FIG. 8.616 FATIGUE STRENGTH OF SMOOTH AND NOTCHED BAR AT LOW TEMPERATURES

(Ref. 8.1)

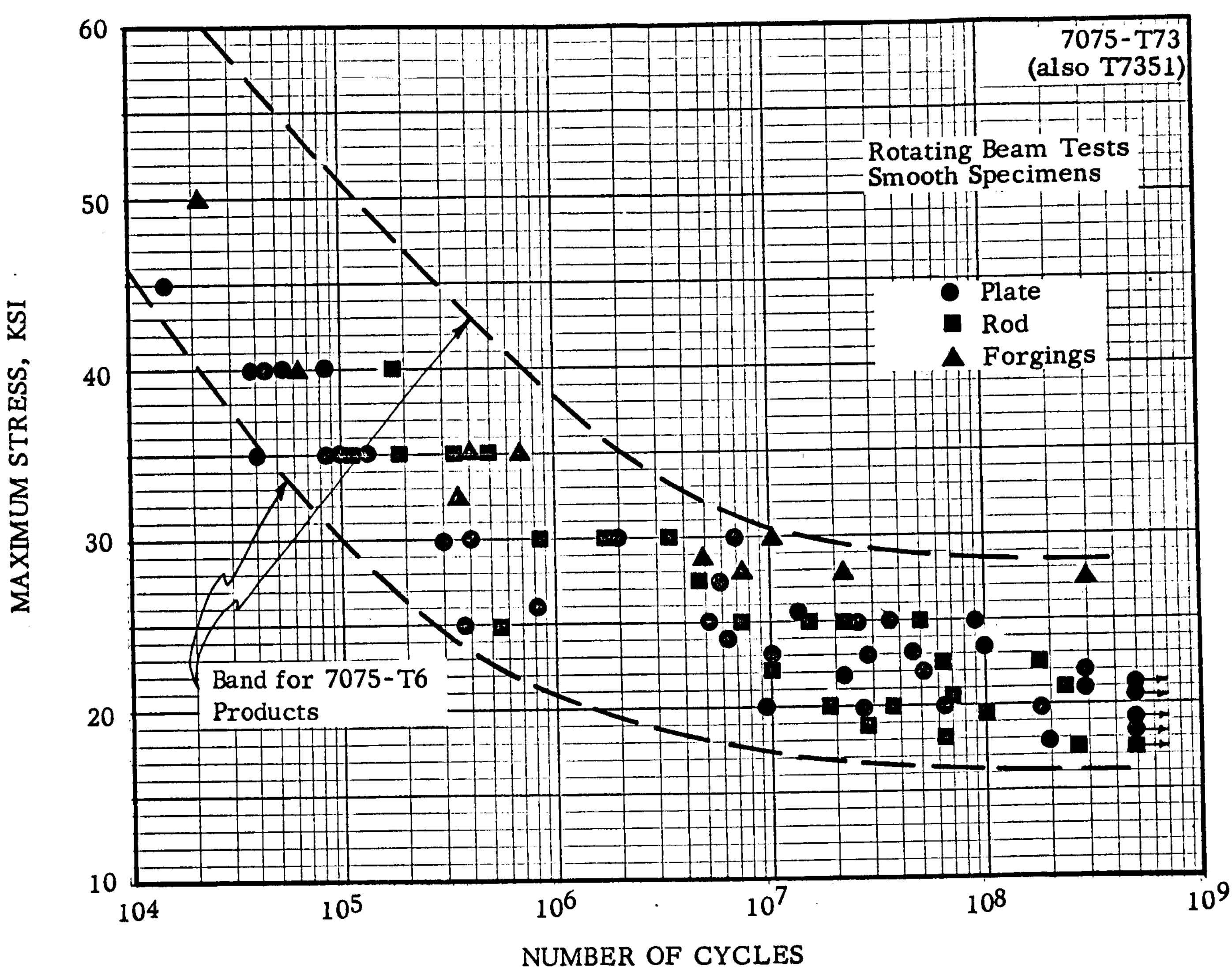

FIG. 8.617 ROTATING BEAM S-N FATIGUE DATA FOR PLATE, ROD AND FORGINGS IN T73 CONDITION

(Ref. 8.12)

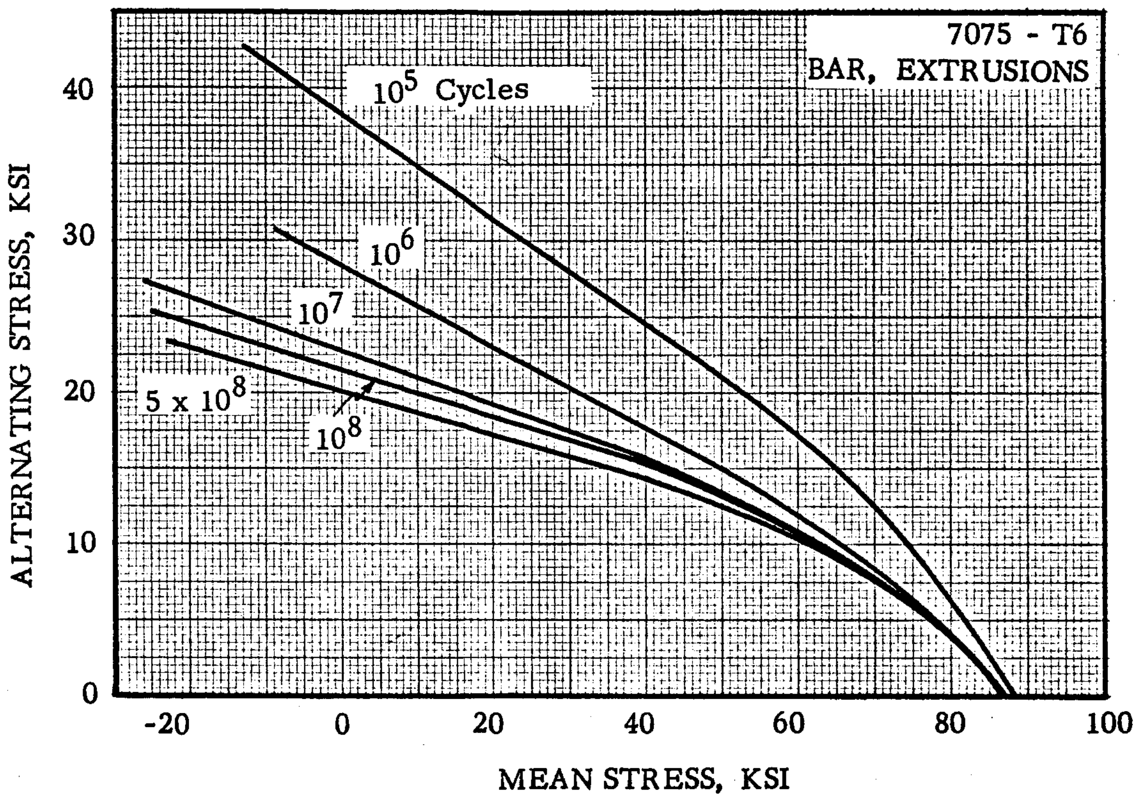

FIG. 8.621 STRESS RANGE DIAGRAM FOR BAR AND EXTRUSIONS IN T6 CONDITION

(Ref. 8.10)

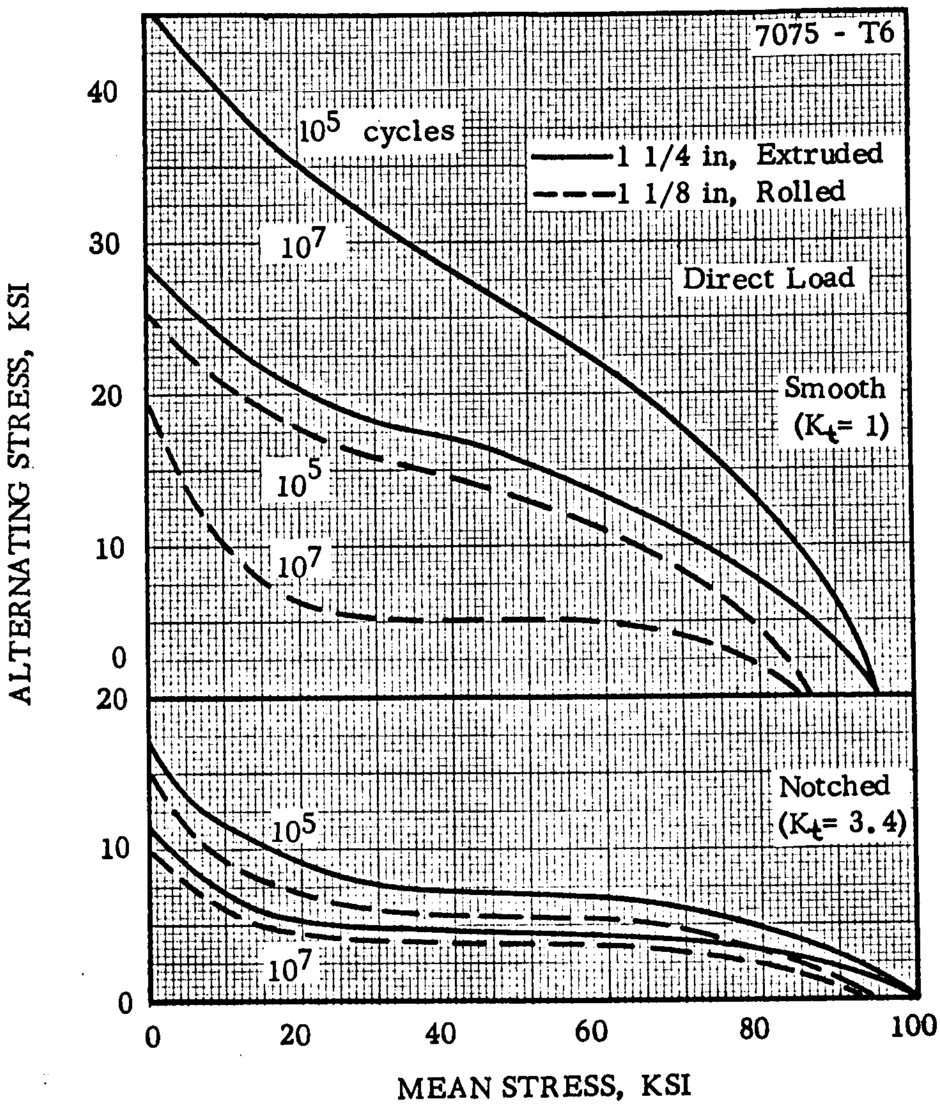

FIG. 8.622 STRESS RANGE DIAGRAM FOR SMOOTH AND NOTCHED BAR AND EXTRUSIONS IN T6 CONDITION (Ref. 8.11)

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CHAPTER 9

PHYSICAL PROPERTIES

9.1 Density (ρ)
0.101 lb/in^3 at 68F
2.80 gr/cm^3 at 20C, (Refs. 9.1 and 9.2).

9.2 Thermal Properties
9.21 Thermal conductivity (K)

Cond T6	0.29 Cal cm per (sec cm^{2}C) at 25C, (Ref. 9.3),	
	76.0 Btu ft per (hr ft^2 F) at 68F, (Ref. 9.1),	
Cond T73	90.0 Btu ft per (hr ft^2 F) at 77F, (Ref. 9.8).	

9.211 Thermal conductivity at various temperatures, Fig. 9.211.
9.22 Thermal expansion (α)

68 to 212F	12.9 x 10^{-6} in per in per °F, (Ref. 9.1),
20 to 100C	23.2 x 10^{-6} in per in per °C, (Ref. 9.3).

9.221 Thermal expansion at various temperatures, Fig. 9.221.
9.23 Specific heat (c_p)
0.23 Btu/lb F at 212F,
0.23 Cal/gr C at 100C, (Ref. 9.1).
9.231 Specific heat at various temperatures, Fig. 9.231.
9.24 Thermal diffusivity

9.3 Electrical Properties
9.31 Electrical resistivity

Cond T6	2.26 microhm-in at 68F, (Ref. 9.2),
	5.2 microhm-cm at 20C, (Ref. 9.5),
	5.7 microhm-cm at 20C, (Ref. 9.6),
	5.74 microhm-cm at 20C, (Ref. 9.3).

9.32 Electrical conductivity

Cond T6	33% of IACS (equal volume) at 68F,
	105% of IACS (equal weight) at 68F, (Ref. 9.5).

9.4 Magnetic Properties. Alloy is non-magnetic.

9.5 Nuclear Properties
9.51 Aluminum alloys with high content of heavy metals such as zinc are not generally used in applications where a high neutron flux is present, since certain isotopes of these heavier metals exhibit long "half-lives", leaving the part "hot" for extended periods. For example, upon extended irradiation of 7075 alloy about half of its 4.5% zinc content may become a gamma emitter whose half-life is about 250 days, (Ref. 9.2).

9.52 Irradiation of 7075-T6 parts, at 6×10^{14} fast nv +, showed no effect on mechanical properties such as shear strength and modulus of rigidity, (Ref. 9.2).

9.6 Other Physical Properties

9.61 Emmisivity in air. 0.035 to 0.07 at 25C, (Ref. 9.7).

9.611 Emissivity is known to be a function of the surface quality of a metal or alloy and the value is also influenced by environment.

9.62 Damping capacity.

9.621 Damping capacity is a function of the hardness or temper of the alloy.

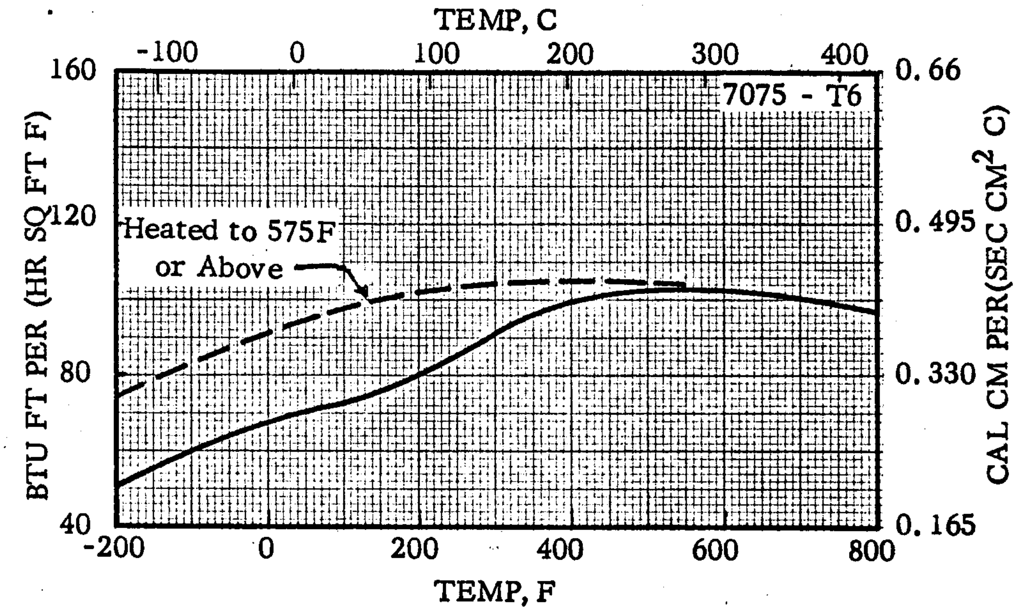

FIG. 9.211 THERMAL CONDUCTIVITY (Ref. 9.2)

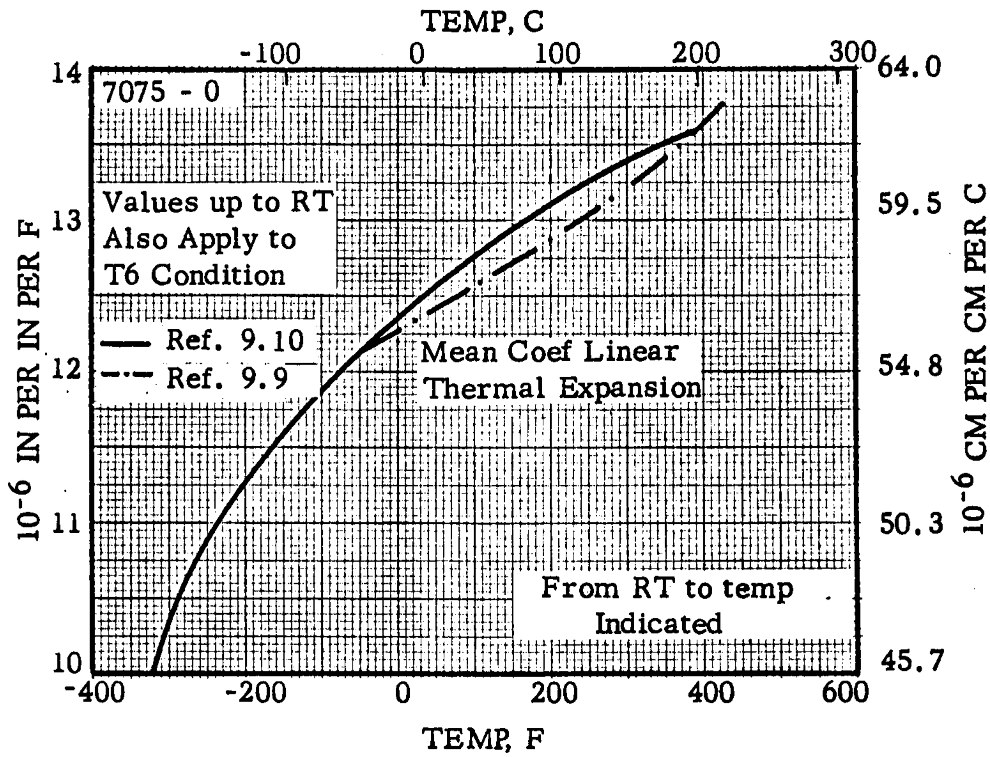

FIG. 9.221 THERMAL EXPANSION (Ref. 9.2)

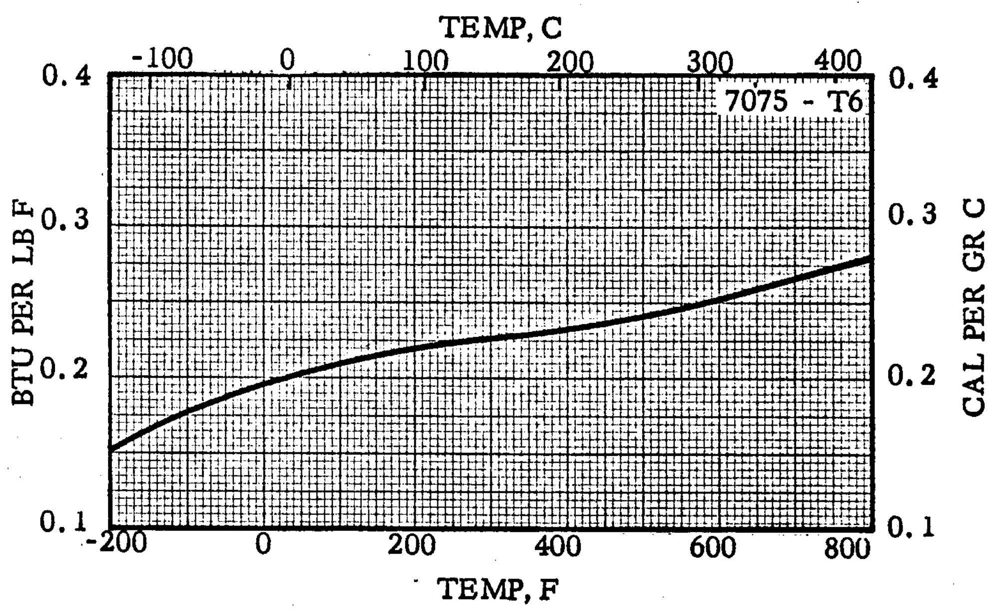

FIG. 9.231 SPECIFIC HEAT (Ref. 9.4)

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CHAPTER 10

CORROSION RESISTANCE AND PROTECTION

10.1 General. Despite its high chemical reactivity and affinity for oxygen, aluminum generally exhibits excellent corrosion resistance in most common environments because it passivates spontaneously and very rapidly under normal oxidizing conditions. The passive film is a hard strongly adhering layer of aluminum oxide, estimated as 20-100Å thick on aluminum exposed to air, (Ref. 10.1), which protects the metal from direct attack. Thus the corrosion rate of aluminum generally decreases with time, except under severe or specific exposure conditions which tend to disrupt the passive film.

Outdoors, aluminum and its alloys weather to a pleasant gray color, with some initial superficial pitting which gradually ceases, (Ref. 10.2). Industrial soot, sulfur dioxide, sulfur trioxide and marine spray tend to increase atmospheric corrosion, but hydrogen sulfide and carbon dioxide do not, (Ref. 10.3). Twenty-year tests at several marine, industrial and rural sites have shown that atmospheric attack on aluminum takes place principally in the first year and progresses very slowly beyond the second year, (Ref. 10.4). Even at high temperatures in dry atmospheres, aluminum is highly resistant to most common gases, except the halogens, (Ref. 10.2).

In aqueous environments, corrosion resistance of aluminum is greatest under neutral or slightly acidic or alkaline conditions, where the protective oxide film is most stable (pH 5.5-8.5 at room temperature, 4.5-7 at 95C), (Refs. 10.1 and 10.5). Strong alkalies and strong-non-oxidizing acids destroy the oxide and greatly accelerate corrosion. Pitting attack occurs in waters containing chloride or other halogen ions, particularly at crevices or stagnant areas where passivity breakdown is accelerated by differential aerative effects. Traces of copper, iron, and mercury ions are also effective in promoting localized attack via galvanic cells formed between aluminum and metal deposited by replacement reactions, (Ref. 10.1). Since aluminum is strongly anodic to most other common metals, galvanic coupling with them generally produces severe attack on the aluminum, especially in sea water, (Ref. 10.2).

Aluminum and its alloys are rather resistant to most molten salts. However, molten metals generally attack aluminum, particularly zinc and tin, which form alloys, (Ref. 10.2). Even a small amount of mercury is especially harmful, since it breaks down passivity and amalgamates, causing rapid perforation of aluminum piping or sheet, (Ref. 10.1). Under some conditions aluminum exhibits very poor resistance to chlorinated solvents and may even react explosively with them; however, such solvents, when properly inhibited, may be used for cleaning and degreasing without harm, (Ref. 10.6).

Aluminum purity significantly affects its corrosion resistance. High purity metal is more resistant than commercially pure aluminum, which in turn is generally more resistant than most alloys, (Ref. 10.1). Corrosion resistance of specific alloys is affected by composition, heat treatment and stress conditions.

The anodic electrode potential of aluminum alloys may cause them to corrode sacrificially when in contact with most other metals in corrosive environments. When possible, direct metallic contact with a more cathodic metal should be avoided. The 7075 alloy, containing both zinc and magnesium in solid solution in aluminum, has an electrode potential that is more anodic than that of pure aluminum. The electrode potentials of aluminum and some alloys are given in Table 10.1.

The corrosion resistance of the 7075 alloy and other aluminum alloys are affected by composition, heat treatment and stress conditions, as discussed further below.

10.2 Resistance of Aluminum Alloy 7075. The general corrosion resistance of the 7075 alloy is good and its resistance is improved with heat treatment and artificial aging. Compared with other aluminum alloys, this alloy exhibits good corrosion resistance to rural atmospheres but is attacked by industrial and marine environments. The 7075 alloy, in general, is less corrosion resistant in most other environments than are the other wrought aluminum alloys. Corrosion resistance is improved by cladding. Alclad sheet and plate are available. The Clad material normally used is a low zinc alloy, 7072, which has a corrosion resistance about equal to that of pure aluminum.

A thermal treatment has recently been developed for the 7075 alloy which provides excellent corrosion resistance. This new temper, designated T73, is highly resistant to stress-corrosion cracking (SCC), does not exfoliate, and is practially immune to intergranular corrosion. The general surface corrosion which occurs in severe environments is predominantly a pitting type for this temper, (Ref. 10.7). Forgings, rolled rod and bar are now regularly produced in the T73 temper. Development, testing and production of 7075-T73 sheet, plate, extrusions and fasteners is also in progress, (Ref. 10.7). In die forgings, the T73 material is guaranteed to be capable of passing the accelerated stress-corrosion test specified in MIL-A-22771. SCC tests were conducted on

205 transverse specimens, from 66 lots, taken across the parting plane of 7075-T73 die forgings. The forgings were of various parts such as tubular fittings, hydraulic cylinders and landing gear sections of various sizes. The test employed was a 3.5 percent NaCl alternate immersion at a stress of 0.75 F_{ty} (42 ksi) for 84 days duration. No failures occurred in any of the 205 specimens, (Ref. 10.7).

In a seacoast atmosphere (Pt. Judith, R.I.), 4 stressed specimens from T73 forgings did not fail after exposure for 46 months. However, 1 of 10 specimens exposed in an industrial environment (New Kensington, Pa.) failed in 28.6 months. Of the remaining 9 specimens, 4 did not fail in 47 months and 5 did not fail in 61 months. These results, and others, indicate that 7075-T73 has excellent resistance to stress corrosion in all directions with respect to grain orientation. It should be noted that the T6 temper exhibits high resistance in the longitudinal and long transverse directions, but is susceptible to stress corrosion cracking in the short transverse direction.

The resistance to stress corrosion of 7075-T6 sheet and forgings, in various environments, is shown in Table 10.2. Comparative data for forgings and for commercial grade plate are presented in Figs. 10.1 and 10.2, respectively.

A study was made to ascertain the effect of short-time exposure of stressed tensile specimens of Clad 7075-T6 sheet to a liquid fluorine environment. Specimens were tested in liquid nitrogen (-320F) to determine F_{tu}, F_{ty} and elongation in a non-reactive environment. Similar determinations were made in an environment of liquid fluorine at -320F, and the specimens were held at a stress equal to 0.9 F_{ty} for 2 hours before continuing the test to failure. A slight decrease in F_{tu} of about 3 percent and a decrease in elongation of about 24% were observed. It was believed that the indicated effect was due to contaminants in the fluorine environment, (Ref. 10.11).

The compatibility of engineering materials with cryogenic and non-cryogenic propellants has been surveyed and reported by the Midwest Research Institute, Kansas City, Missouri, (Ref. 10.12).

This report indicated that the 7075 alloy is compatible with the following propellants under most conditions for long term applications:

> Liquid oxygen (LOX); (non-corrosive but embrittlement may occur due to low temperature).
>
> Aerozine-50; (50% Hydrazine/50% UDMH) at 160F.
>
> Unsymmetrical Dimethylhydrazine (UDMH) at 160F maximum.

Hydrazine (N_2H_4); (some authorities disagree, however).

Nitrogen tetroxide (N_2O_4); (O and T6 Conditions if less than 0.2 and 0.6% H_2O is present).

Pentaborane (B_5H_9); T6 Condition

10.3 Protective Measures. Anodic coatings are widely used for the corrosion protection of aluminum alloys. These oxide coatings are hard and are abrasion and corrosion resistant. Cathodic protection has also proved effective in retarding both general dissolution and localized attack, although overprotection by this method should be avoided to insure against harmful accumulation of alkali at the cathode surface, (Ref. 10.1).

Painting and inorganic inhibitors have also been applied with success in specific cases, (Ref. 10.2).

The 7075 alloy is available as Alclad sheet and plate which consists of bare 7075 with a thin coating of 7072 alloy on one or both surfaces. The Clad alloy is chosen to provide a surface having a high resistance to corrosion and sufficiently anodic to the 7075 core material to afford electrochemical protection.

Surface treatments are discussed in greater detail in Chapter 11.

ELECTRODE POTENTIALS OF ALUMINUM AND SOME ALLOYS

TABLE 10.1

Source	(Ref. 10.8)
Property	Electrode Potentials vs 0.1 N Calomel at 25° C
(Aqueous solution of 53 gr NaCl and 3 gr H_2O_2 per liter)	
Al + Zn + Mg (4% $MgZn_2$ solid solution)	−1.07 Volt
Al + Zn (4% Zn solid solution)	−1.05 Volt
Alclad 7075	−0.96 Volt
5456 Alloy	−0.87 Volt
Al (99.95 + %)	−0.85 Volt
6061-T6	−0.83 Volt
7075-T6	−0.81 Volt
2014-T6	−0.78 Volt
2014-T4 and 2024-T4	−0.70 Volt
Mild Steel	−0.58 Volt

TABLE 10.2

Alloy	Environment*	Exposure	Tension Specimen, % Failed†	Average Loss in Tensile Strength	
				Unstressed	Stressed†
2014-T 6	3½% NaCl	84 days	0%	42%	55%
	Seacoast	365	0	18	28
	Inland industrial	365	0	7	7
2219-T 81	3½% NaCl	84	0	21	26
	Seacoast	365	0	6	8
	Inland industrial	300	0	—	—
2024-T 3	3½% NaCl	84	0	33	40
	Seacoast	365	0	16	20
	Inland industrial	365	0	6	9
7075-T 6	3½% NaCl	84	6	13	22
	Seacoast	365	10	7	10
	Inland industrial	365	0	2	5
7178-T 6	3½% NaCl	84	0	14	24
	Seacoast	368	20	8	18
	Inland industrial	365	0	1	3

Specimens were taken from production sheet, 0.063 in. thick.
*Specimens exposed to 3½% NaCl were alternately immersed.
†Stressed 75% of yield strength.

Surface Treatment	Protective Coating	Specimen Life, Days	
		3.5% NaCl Alternate Immersion	Industrial Atmosphere
As machined	None	1, 5, 5, 17, 28	20, 37, 120, 161
Shot-blast (#230 steel shot)	None	OK 365*, OK 730*	OK 3111
Grit blast (#25 steel grit)	None	5, 9, 11, 108, OK 182*, OK 570*	1549, 1825, 2536
As machined	CrO_3 anodic + paint†	OK 198*, OK 270*, OK 365, OK 1095*	1493
Grit blast (#25 steel grit)	CrO_3 anodic + paint‡	1395, OK 1825‡	OK 3471, OK 3471‡
Grit blast (#25 steel grit)	7072 metal spray (1 to 3 mils)	182, 1469, 2 OK 1095*, 1 OK 1825	268, 3 OK 3471
Grit blast (#25 steel grit)	7072 metal spray + paint†	OK 806*	OK 3471

Product: 7075-T 6 forging 6 by 15 by 20 in.; specimen: short transverse 0.437-in. diameter tension bar; stress: 75% of yield strength. All grit and shot-blasting was done on specimens prior to stressing.
*Removed from test because specimen fractured in threaded grip.
†Zinc chromate primer plus coat of aluminum paint.
‡Zinc chromate primer plus two coats of aluminum paint.

(Ref. 10.9)

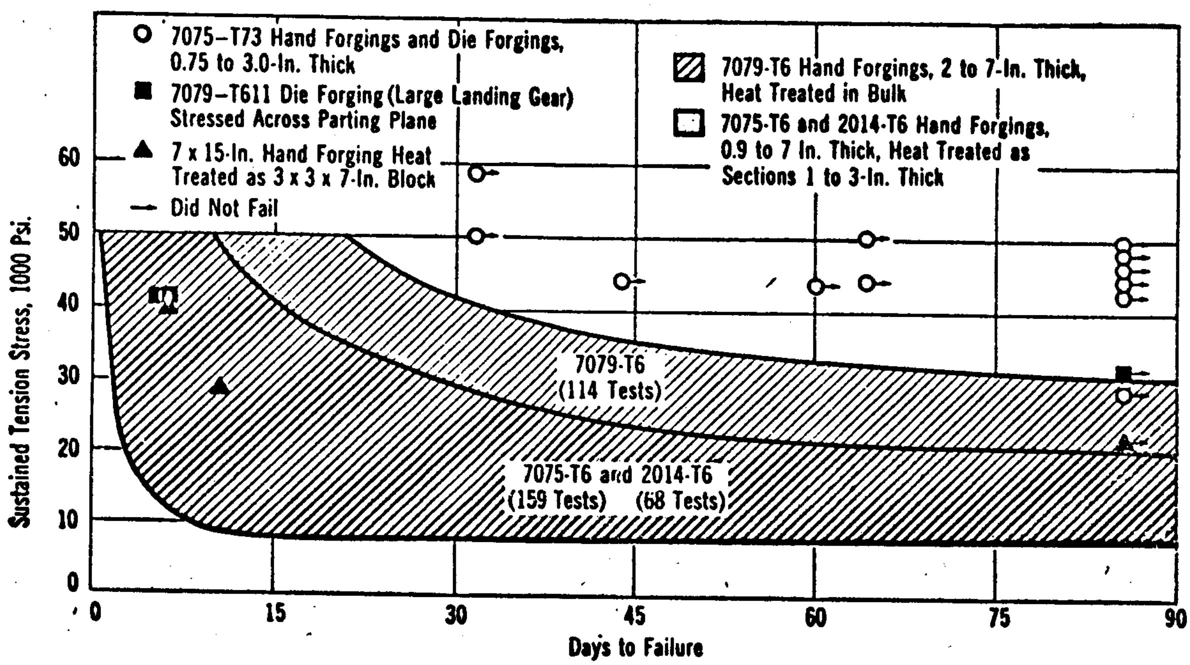

FIG. 10.1 COMPARATIVE STRESS CORROSION PERFORMANCE OF ALUMINUM ALLOY FORGINGS. ALTERNATE IMMERSION IN 3.5% NaCl SOLUTION (Ref. 10.9)

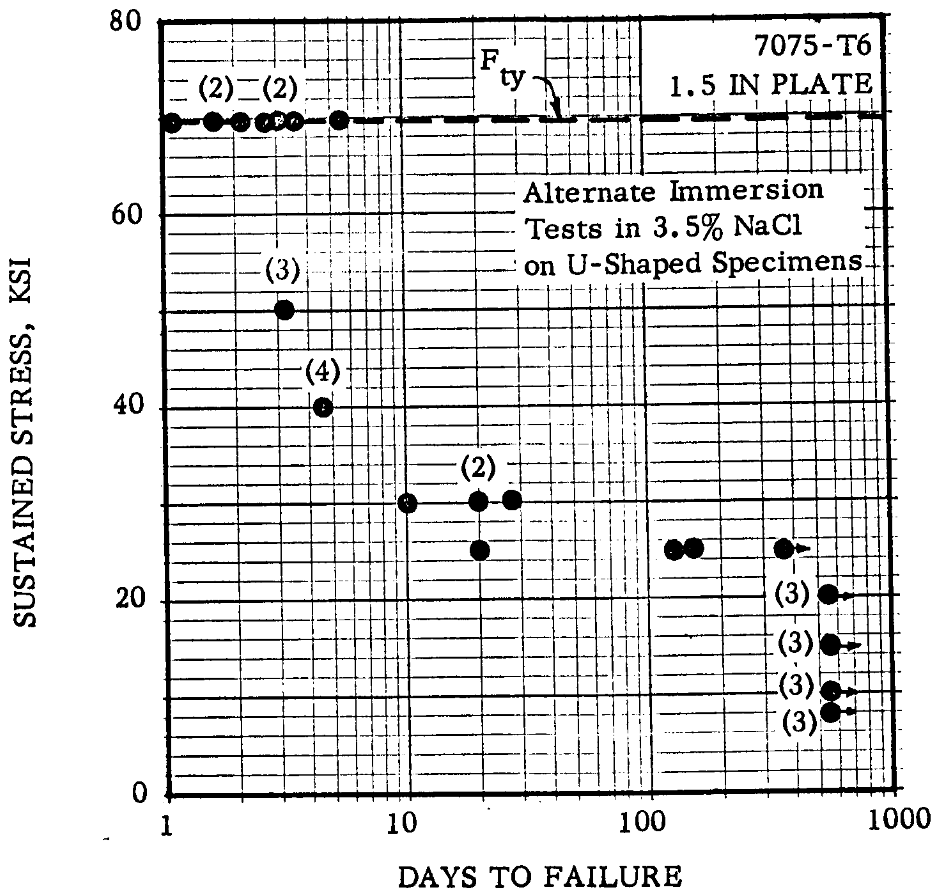

FIG. 10.2 RESULTS OF STRESS CORROSION TESTS ON T6 PLATE

(Ref. 10.10)

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CHAPTER 11

SURFACE TREATMENTS

11.1 General. A wide variety of surface treatments can be applied to the 7075 alloy (and other aluminum alloys) to protect and improve the appearance of the surface. These include mechanical, chemical and electrochemical finishes and organic, porcelain and paint coatings. Alclad forms of aluminum alloys have a very high inherent resistance to corrosion and may be used without benefit of protective coatings for some applications, (Ref. 11.1).

11.2 Alclad Products. The 7075 alloy is available as Alclad sheet and plate which consists of bare 7075 core material clad with a thin coating of 7072 alloy on one or both sides. The Clad material is metallurgically bonded to the core material. It is chosen to provide a surface having a high resistance to corrosion and sufficiently anodic to the 7075 core to afford electrochemical protection to it in corrosive environments. Consequently, any spot of attack can penetrate only as deep as the core alloy where further progress is stopped by cathodic protection. Corrosion is thus confined to the Clad material only. The life of the cladding is a function of its thickness and the severity of the environment. Alclad products, therefore, limit corrosion to a relatively thin Clad surface layer, (Refs. 11.2 and 11.8).

11.3 Mechanical Finishes. Mechanical finishes are used to alter the texture of the alloy surface to provide a more decorative appearance or as a treatment prior to other finishing such as painting. Grinding, polishing and buffing result in smoother reflective surfaces. Abrasive blasting (sand or grit) gives a rough matte finish which is often used as a base for organic coatings. Scratch finishing, satin finishing, Butler finishing and skin finishes are scratched-line finishes which remove minor surface defects and provide a decorative effect. Mechanical methods remove the original heavy oxide film. For this reason mechanically finished parts are often given a protective coating by anodizing or lacquering. The possibility of generating an explosive mixture of fine powder and air during mechanical finish operations should be recognized, (Ref. 11.3).

11.4 Anodizing. Anodic coatings are hard, abrasion and corrosion resistant oxide coatings. The alloys can be anodically coated in a number of electrolytes, but most commercial anodizing is done by either the sulfuric acid or chromic acid process. The thickness of the coating is dependent upon the anodizing time. Coatings produced by the sulfuric acid process vary in thickness from 0.0001 to 0.001 inch. Coatings produced in chromic acid vary from 0.00001 to 0.00009 inch. Anodic coatings provide good protection against corrosion and are excellent bases for paint coatings, (Ref. 11.1). However, the chromic acid process does not provide as corrosion resistant a coating as does the sulfuric acid process, (Ref. 11.10).

11.41 In recent years a number of new methods have been developed for producing heavier anodic coatings of from 0.001 to 0.010 inch. These methods require electrolytes which enable the oxide growth process to continue until the desired coating thickness is obtained.

Another recent development in coatings is that of hard anodizing, designated as "hardcoatings". Processes most suitable for a wide range of applications are Alumilite 226 (oxide coatings, 0.002 inch thick) and Martin Hardcoat (coating thicknesses up to 0.004 inch). A flash hardcoat of a very thin film can also be applied by these methods by shortening the normal time cycle. The operating conditions for the two baths employed for these processes are given in Table 11.1. The Martin process should be specified where maximum hardness and corrosion resistance are required along with thickness buildups to 0.004 inch. Alumilite 226 is selected where hardness and corrosion resistance are required and 0.002 inch is the acceptable maximum buildup. Further details of these processes are presented in Ref. 11.9.

11.5 Chemical Finishes. Chemical finishes are of three main types. Finishes used for decorative effects include caustic etching, acid etching and chemical polishing. Etched surfaces have a matte appearance while chemically polished surfaces are highly reflective and require protection by anodizing or lacquering.

Conversion coatings can be oxide, phosphate or chromate types and are used primarily as base coatings prior to application of organic coatings. Miscellaneous special-purpose finishes include those produced by the Alrok process, Modified Bauer-Vogel process and processes for staining aluminum alloys.

11.6 Electropolishing. This process produces a highly reflective surface and is often used for surface preparation prior to microscopic examination of metallurgical structure.

11.7 Electroplating of aluminum alloys has gained increased commercial use in recent years. A commonly used finish consists of successive deposits of copper, nickel and chromium. Other metals may be applied over the copper. A satisfactory base surface for electroplating is provided by immersing the aluminum part in a solution of sodium zincate of controlled composition. Brass, iron, silver or chromium can be applied directly over this zinc immersion coating, (Ref. 11.4).

11.8 Painting. When severe conditions of exposure are to be encountered, it is frequently desirable to protect aluminum alloy surfaces with paint. Prior to painting, the surface should be properly prepared before priming. A clean and dry surface, one free from grease, dirt, dust, moisture, and foreign matter, is of prime importance. For adequate adhesion and maximum corrosion protection, a chemical conversion coating per Mil-C-5541 or anodic coating per Mil-A-8625 should be applied. The properly treated surfaces are then primed with a zinc chromate primer per Mil-P-8585. For less severe environments or wherever it is impractical to apply the pretreatment coatings, a chemical cleaning per Mil-M-10578B (phospheric acid metal conditioner) or a mild mechanical cleaning are sometimes employed. These are followed by a chromate pigmented primer.

For severe conditions of exposure, both primer and joint compound should be used at joints.

All surfaces except contacting surfaces may be given a second coat of paint consisting of two pounds of aluminum paste pigment (ASTM Spec. D 962, Type II, Class B.) per gallon of varnish which meets Federal Spec. TT-V-86b, Type II or equivalent. The final assembled structure may be finished with one coat of aluminum paint. One or more coats of alkyd base enamel (pigmented to desired color) may be substituted for aluminum paint, (Ref. 11.5).

11.81 To minimize stress-corrosion cracking when the alloy is subjected to sustained surface stresses and corrosive environments, certain surface treatments and protective coatings are effective. The most effective protection is obtained by applying a topcoat of epoxy-polyamide paint to shot-peened or metallized surfaces of the alloy. Satisfactory temporary protection is obtained by an electroplated galvanic coating (3 to 4 mils thick), or a topcoat of paint containing epoxy-polyamide or polyurethane resins. The former is preferred and can be used on unprimed surfaces. Care is necessary to prevent breaking or scratching the paint film. Shot peening alone will provide good surface protection (if all surfaces are treated) when corrosive environment is not severe. Anodic films and zinc-rich paints are the least effective coatings for preventing stress-corrosion cracking, (Ref. 11.6).

11.9 Porcelain Enameling. The principal difference between porcelain enameling of aluminum alloys and other metals is the use of porcelain frits, which melt at lower temperatures. High lead frits are commonly used and they can be formulated in a wide variety of colors and surface finishes. The enamel slip is sprayed onto chemically cleaned and treated surfaces and then fired at temperatures of 950 to 1050F for a period of 4 to 8 minutes, (Ref. 11.7).

TABLE 11.1

Source	Ref. 11.9	
Alloy	Aluminum Wrought Alloys	
Data	Baths for Hard Anodized Coatings	
	Process	
	Martin (a)	Alumilite (b)
Composition	15% H_2SO_4	12% H_2SO_4 1% $H_2C_2O_4$
Electrolyte Temp, F	25 to 32	48 to 52
Current Density	25 asf	36 asf

(a) Developed by the Martin Co.

(b) Developed by the Aluminum Co. of America

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CHAPTER 12

JOINING TECHNIQUES

12.1 General. The 7075 alloy is not considered to have good fusion weldability in any temper and fusion welding of this alloy is not normally recommended. The alloy is also difficult to weld in the annealed condition (O temper) by resistance welding techniques. Resistance welding of all heat treated tempers, however, is successfully accomplished if special practices are employed.

Brazing, gas welding or soldering of 7075 is not recommended, as satisfactory methods have not as yet been developed for this alloy. The alloy can be satisfactorily joined by riveting or bolting, (Refs. 12.4, 12.5, 12.7 and 12.8).

12.2 Welding

12.21 Fusion Welding. Fusion welding of the 7075 alloy is not normally recommended, as satisfactory methods have not been developed for this alloy.

12.22 Electrical Resistance Welding. Resistance welding (spot welding or seam welding) is a most useful and economical method of joining aluminum alloys. Satisfactory spot or seam welds are made in 7075 material in all heat treated tempers by resistance methods, but special practices are required. Mechanical or chemical cleaning of the contact surfaces is necessary to obtain consistent and sound welds. In aircraft construction, it is recommended that the contact resistance of the elements to be joined be continually checked to ensure surface cleanliness. For best results, the surface contact resistance should not exceed 50 microhms. Details on surface cleaning are given in Ref. 12.4. The choice of the type of resistance welding machine for spot or seam welding of aluminum alloys depends partly on the power supply, its voltage drop characteristics, demand limitations and other similar factors. A more detailed discussion of resistance welding equipment is given in Refs. 12.4 and 12.9.

12.23 Mechanical Properties of Spot Welds. The strength of spot welded joints depends to a large extent upon the static strength of each single weld spot. The static strength of typical single spot welds in tension is given in Fig. 12.1 for 7075-T6 Clad sheet of various thicknesses. The maximum static strength of spot welded joints, and corresponding maximum spot weld pitch for T6 Clad sheet, are presented in Table 12.1.

The suggested minimum joint overlap and spacing of spot welds is given in Table 12.2 and the minimum allowable edge distance for spot-welded joints is shown in Table 12.3.

Spot weld maximum design shear strength in panels is presented in Table 12.4 for bare and Clad alloys. The efficiency of the parent metal in tension for various spot weld spacings is given in Fig. 12.2.

The use of spot welds on military structural parts is governed by the requirements of the procuring or certificating agency, (Ref. 12.6). The requirements for equipment, materials and production control of spot and seam welds in aluminum alloys is covered by military specification MIL-W-6858C.

12.3 Brazing. Brazing or soldering of the 7075 alloys is not recommended, (Ref. 12.5)

12.4 Riveting. Riveting is the most commonly used method for joining this alloy. Riveting methods are highly developed and are largely independent of the operator's skill. Thus, uniformity of riveted joints can be readily attained, (Ref. 12.10). Specifications for riveting of aluminum alloys are listed in Table 12.5.

12.41 Aluminum alloy rivets are preferred for the fabrication of aluminum alloy structures, although cold-driven annealed steel rivets have been used successfully for certain applications. To determine the strength of riveted joints, it is necessary to know the strength of the individual rivet. In most cases, failure of such joints occurs by shearing, in bearing or tearing of the sheet or plate. Table 12.6 gives the average shear strength of driven rivets of various aluminum alloys. These values may be considered representative of properly driven rivets, although occasional driven rivets may fall below the average by 5 or 10 percent. It is customary to use a slightly larger factor of safety for the shear strength of rivets than is employed for other parts of an assembly. The design of joints where rivets are subjected to tensile loads should be avoided. Bolted connections may be used where high tensile stresses preclude the use of riveting. Information in greater detail on the riveting of aluminum alloys is given in Refs. 12.11 and 12.12. Design data on mechanical joints using rivets or bolts may be found in Military Handbook - 5, (Ref. 12.6).

MAXIMUM STATIC STRENGTH OF SPOT-WELDED JOINTS AND CORRESPONDING MAXIMUM SPOT-WELD PITCH (a)

TABLE 12.1

Source	(Ref. 12.6)			
Alloy	7075 - T6 Clad			
Thickness of Thinnest Sheet, in	Single Row Joints		Multiple Row Joints	
	Strength lb/in	Pitch in	Strength lb/in	Pitch/No of Rows, in
0.010	288	0.167	438	0.110
0.012	346	0.173	526	0.114
0.016	461	0.191	701	0.126
0.020	577	0.194	876	0.128
0.025	721	0.205	1095	0.135
0.032	923	0.225	1402	0.148
0.040	1059	0.261	1752	0.158
0.050	1230	0.302	2190	0.170
0.063	1452	0.369	2759	0.194
0.071	1589	0.415	3110	0.212
0.080	1742	0.471	3504	0.234
0.090	1913	0.525	3942	0.255
0.100	2084	0.572	4380	0.272
0.112	2289	0.622	4096	0.290
0.125	2511	0.675	5475	0.310

(a) For multiple row joints row spacing is at minimum and same pitch in all rows.

TABLE 12.2

Source	Ref. 12.4	
Alloy	Aluminum Alloys	
Data	Suggested minimum joint overlap and spacing of spot welds	
Thinnest sheet in joint, inch	Minimum joint overlap, inch	Minimum weld spacing, in
0.016	5/16	3/8
0.020	3/8	3/8
0.025	3/8	3/8
0.032	1/2	1/2
0.040	9/16	1/2
0.051	5/8	5/8
0.064	3/4	5/8
0.072	13/16	3/4
0.081	7/8	3/4
0.091	15/16	7/8
0.102	1	1
0.125	1 1/8	1 1/4

TABLE 12.3

Source	Ref. 12.6
Alloy	Aluminum Alloys
Property	Minimum allowable edge distances for spot-welded joints (a)(b)(c)

Nominal thickness of the thinner sheet, in	Edge distance, E, in
0.016	3/16
0.020	3/16
0.025	7/32
0.032	1/4
0.036	1/4
0.040	9/32
0.045	5/16
0.050	5/16
0.063	3/8
0.071	3/8
0.080	13/32
0.090	7/16
0.100	7/16
0.125	9/16
0.160	5/8

(a) Intermediate gages will conform to the requirement for the next thinner gage shown.

(b) Edge distances less than those specified above may be used provided there is no expulsion of weld metal or bulging of the edge of the sheet or damage to bend radii by electrode.

(c) Values may be reduced for non-structural applications or applications not depended on to develop full weld strength.

SPOT WELD MAXIMUM DESIGN SHEAR STRENGTH IN PANEL FOR BARE AND CLAD ALUMINUM ALLOYS (WELD SPEC. MIL-W-6858)

TABLE 12.4

Source	Ref. 12.6			
Alloy	Aluminum Alloys, (bare and clad)			
Property	Spot weld maximum design shear strength in panels (a)(b)(c)			
Nominal thickness of thinner sheet, inch	Material ultimate tensile strength			
	≥ 56 (ksi)	20 to 56 (ksi)	19.5 to 28 (ksi)	< 19.5 (ksi)
0.010	48	40	-	-
0.012	60	52	24	16
0.016	88	80	56	40
0.020	112	108	80	64
0.025	148	140	116	88
0.032	208	188	168	132
0.040	276	248	240	180
0.050	372	344	320	236
0.063	536	488	456	316
0.071	660	576	516	360
0.080	820	684	612	420
0.090	1004	800	696	476
0.100	1192	936	752	540
0.112	1424	1072	800	588
0.125	1696	1300	840	628
0.160	2496	1952	-	-
0.190	3228	2592	-	-
0.250	5880	5120	-	-

(a) The reduction in strength of spotwelds due to cumulative effects of time-temperature-stress factors is not greater than the reduction in strength of the parent metal.

(b) Strength based on 80 percent of minimum values specified in MIL-W-6858.

(c) The allowable tensile strength of spotwelds is 25 percent of the shear strength.

TABLE 12.5

Source	Ref. 12.1 and 12.3		
Item	Specifications for Rivets (Aluminum)		
Products	Specifications		
	Federal	Military	AMS
Rivets	FF-R-556a	MIL-R-1150A-1	7220C
	-	MIL-R-5674B-1	7222C
	-	MIL-R-12221B	7223
Rivets, blind	-	MIL-R-7885A-1	-
	-	MIL-R-8814-1	-
	-	MIL-R-27384	-
Rivet, wire	QQ-A-430-1	-	-

TABLE 12.6

Source	Ref. 12.11		
Data	F_{su} (Average) for Driven Rivets (c)		
Alloy and Temper before Driving (a)	Driving Procedure	Alloy and Temper after Driving	F_{su} (Aver) (ksi)
1100-H14	Cold, as received	1100-F	11
2017-T4	Cold, as received	2017-T3	39
2017-T4	Cold, immediately after quenching	2017-T31	34(b)
2024-T4	Cold, immediately after quenching	2024-T31	42(b)
2117-T4	Cold, as received	2117-T3	33
5056-H32	Cold, as received	5056-H321	30
6053-T61	Cold, as received	6053-T61	23
6061-T4	Cold, immediately after quenching	6061-T31	24(b)
6061-T4	Hot, 990 to 1050F	6061-T43	24(b)
6061-T6	Cold, as received	6061-T6	30
7277-T4	Hot, 850 to 975F	7277-T41	38

(a) These designations should be used when ordering rivets.

(b) Immediately after driving, the shear strengths of these rivets are about 75% of the values shown. On standing at ambient temperatures, they age harden to develop full shear strength. This action takes about 4 days for 2017-T31 and 2024-T31 rivets. Values shown for 6061-T31 and 6061-T43 rivets are attained in about 2 weeks. Values of 26 ksi are attained by 6061-T31 rivets about 4 months after driving. Values shown for 7277-T41 rivets are attained in about one week.

(c) These values are for rivets driven with core point heads. Rivets driven with heads requiring more pressure may be expected to develop slightly higher strengths.

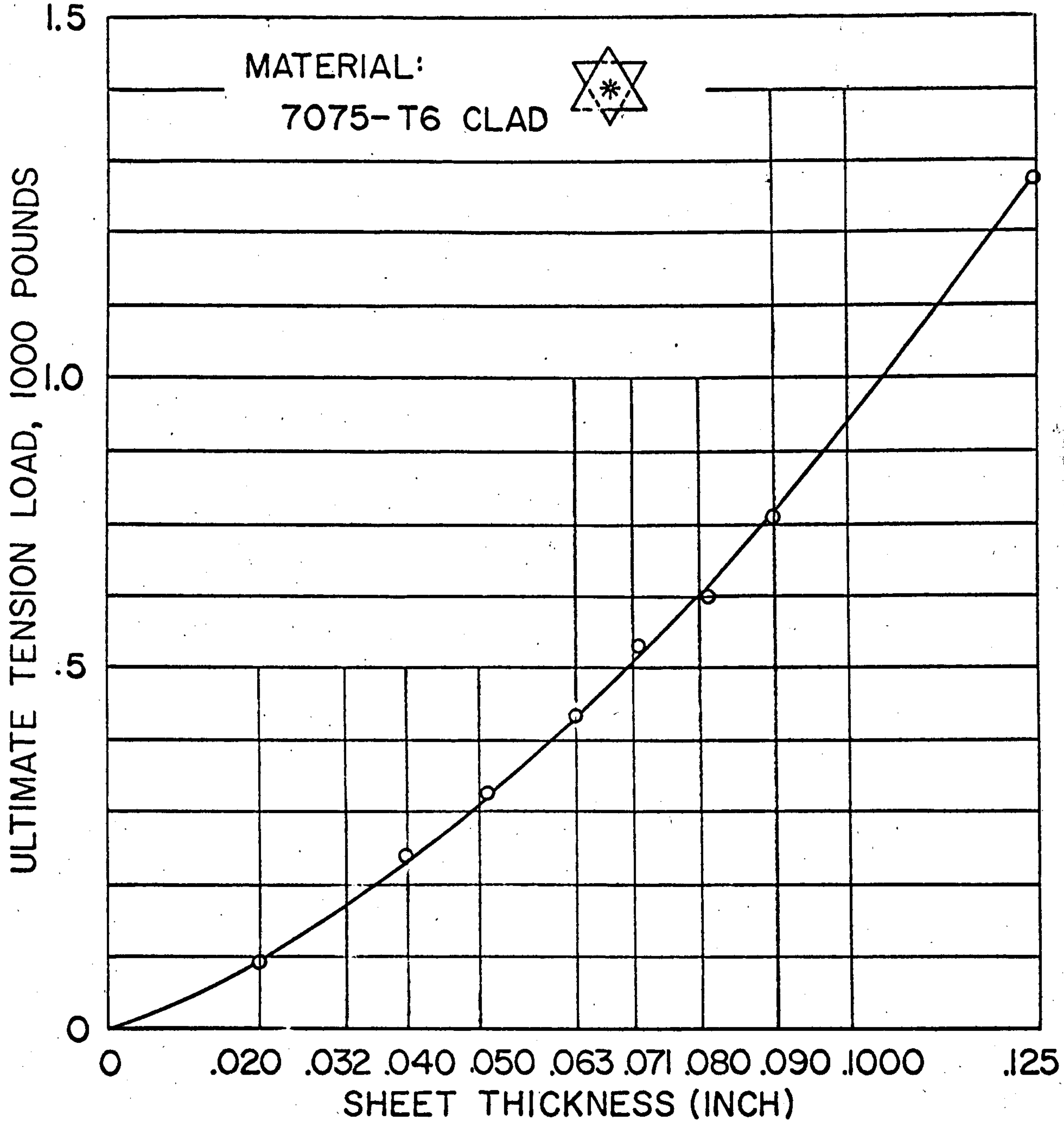

FIG. 12.1 STATIC STRENGTH OF TYPICAL SINGLE SPOT WELDS IN T6 CLAD SHEET OF VARIOUS THICKNESSES (Ref. 12.6)

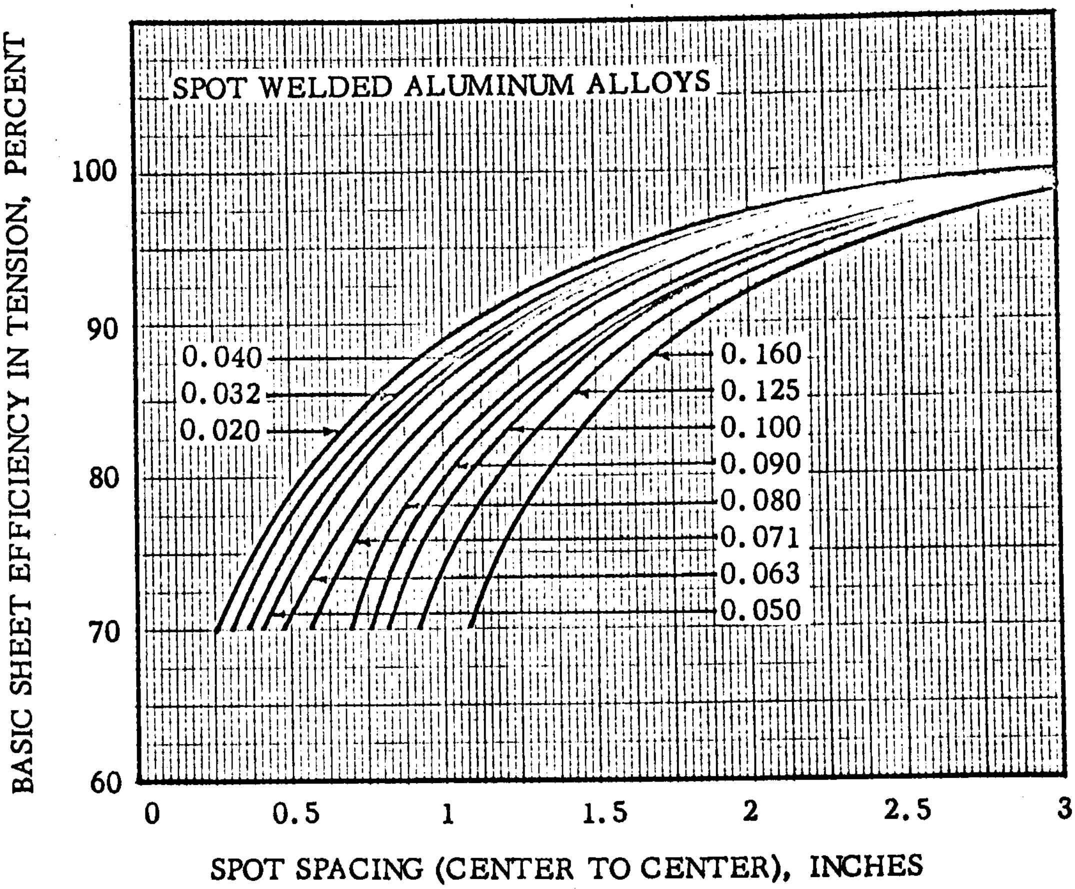

FIG. 12.2 EFFICIENCY OF THE PARENT METAL IN TENSION FOR SPOT WELDED ALUMINUM ALLOYS

(Ref. 12.6)

CHAPTER 12 - REFERENCES

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12.7 "Aerospace Structural Metals Handbook", V. Weiss and J. Sessler (Editors), ASD-TDR-63-741, Vol. II, (March 1963)

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12.12 "Riveting Alcoa Aluminum", Aluminum Co. of America, (1960)